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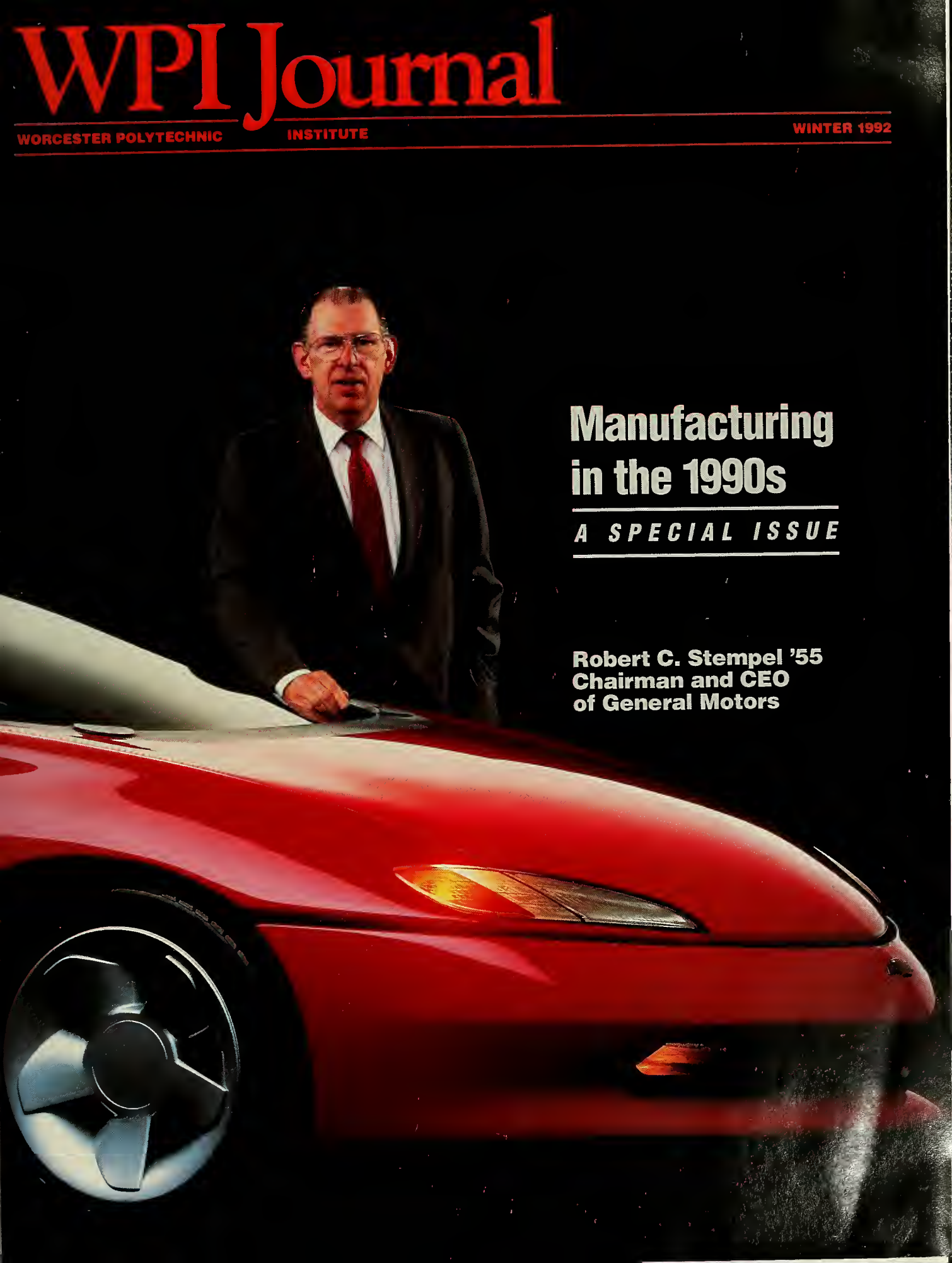

Manufacturing in the 1990s

A SPECIAL ISSUE

Robert C. Stempel '55
Chairman and CEO
of General Motors

WPI Journal

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Front Cover: Robert C. Stempel poses with a General Motors concept car. Story on page 2. Photo courtesy General Motors. **Opposite:** Paul Cotnoir, director of the Manufacturing Engineering Applications Center, left, and graduate student Fredric Gold use a boroscope to examine the transmission housing of a Bradley Fighting Vehicle. Story on page 21. Photo by Janet Woodcock. **Back Cover:** A detail from a hand-colored engraving of the WPI campus by Richard Rummell, completed in 1908. WPI has launched a drive to endow the maintenance of its academic buildings, including Boynton Hall, Stratton Hall and the Washburn Shops, seen here from left to right. Story on page 34. (Note: Alumni Gymnasium, completed in 1916 and seen in the background, was added to this print at a later date.)

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What's Good for General Motors Today?

By Michael Dorsey

After a decade of dramatic change, the world's largest manufacturer is striving to become a smaller, leaner and more efficient corporation to better face the enormous pressures of foreign competition, and to better survive one of the longest recessions in recent memory.

What did GM learn during the tumultuous 1980s about building high-quality products, about balancing automation and human resources, and about competing in the global marketplace, and how is it putting those lessons to work to tackle the challenges it faces today? GM's chairman and CEO, WPI's own Robert C. Stempel '55 (left), provides some answers.

In 1952 President Eisenhower nominated Charles "Engine Charlie" Wilson, a former General Motors president and a major GM stockholder, to be his secretary of defense. Asked whether his ties to a corporation that counted defense contracts as an important part of its bottom line would pose a conflict of interest in his new job, Wilson replied, "For years I've thought what was good for the country was good for General Motors, and vice versa."

While General Motors' impact on the well-being of the United States may have diminished somewhat since those days, it is still the largest and most important manufacturing company in the world. Its work force numbers close to half a million. About 10,000 dealers sell its products. Some 30,000 suppliers provide it with parts and raw materials, and its assembly lines are the nation's largest consumers of steel, rubber, glass and plastic.

It's not surprising, then, that decisions made in the 14th-floor executive offices of the General Motors Building in Detroit have the power to captivate the international business press, and quickly become the focus of conversations around water coolers and dinner tables from coast to coast.

Such was the case on Dec. 18, 1991, when Robert C. Stempel '55, a 33-year General Motors veteran who became chairman and CEO 18 months ago, stood before a packed press conference and announced a major resizing of the corporation. Over the next five years, Stempel said, GM will close 21 of its 125 assembly and parts plants, reducing its capacity by one-fifth, and eliminate 74,000 blue- and white-collar jobs (nearly 18 percent of its North American work force), shrinking the company to about half its 1985 size.

The announcement was the latest step in a series of actions—including an historic $2.1 billion special charge against earnings in 1990—that GM has taken over the last few years to improve its competitiveness, productivity and profitability by bringing its manufacturing capacity and payroll in line with its worldwide auto sales. Those sales have been declining in recent years due chiefly to the erosion of consumer confidence brought on by a lingering recession.

In 1991, for example, sales of GM vehicles fell by about 600,000 over 1990 levels, leaving the company facing losses of up to $3 billion (GM last earned a profit—$4.85 billion—in 1989). The drop in earnings followed a decade in which the company's share of the North American market steadily declined.

GM, which once made 52 percent of all cars sold in the U.S., saw its market share drop from 46 percent in 1980 to just over 35 percent by the end of 1991. Over the same period, the share held by Japanese automakers rose from 15.7 percent to 29 percent. Significantly, the size of that market has also declined—from about 14 million vehicles in 1980 to about 12 million vehicles today.

How did General Motors arrive at this critical era of belt-tightening? How did a corporation that once seemed the stable, solid heart of American enterprise find itself in the midst of an urgent quest to rebuild and remake itself? Much of the answer lies in the events of the 1980s, 10 years of dramatic change at GM, and a decade that posed some of the most significant challenges the corporation has faced in its 83-year history.

Several critical events in the 1970s paved the way for the eventful '80s. The most important was the oil embargo of 1973, which sent gasoline prices soaring and created a tremendous demand for smaller, more fuel-efficient cars. American car companies responded with models like the Ford Pinto and the Chevrolet Vega, but consumers seemed to prefer imports like the Honda Civic. In fact, Japanese carmakers made significant inroads into the U.S. car market during the rest of the 1970s.

In 1978 the U.S. was hit with another oil embargo and the federal government introduced the first fuel-economy standards for cars. General Motors, which had already begun a program to downsize its larger cars, accelerated that program and set out to make virtually every one of its vehicles smaller, lighter and more fuel efficient.

The oil embargoes, combined with a recession in the mid-1970s, led to declining sales for all three U.S. automakers. In response, GM laid off thousands of workers in 1979, and the following year the company posted its first yearly loss in 60 years—$763 million. As the 1980s began, it was becoming clear to many that American automakers had a bigger problem: the Japanese were beating the Big Three American automakers in two critical areas—quality and cost. By selling cars that appealed to U.S. consumers and keeping their manufacturing costs down, the Japanese were giving GM, Ford and Chrysler a run for their money.

Some of the ways in which GM responded to the competitive pressures of the early 1980s were destined to erode consumer confidence. For example, the move to downsize cars resulted in car series—the J-cars of the early 1980s, for example, or the GM-10 series introduced later in the decade—with models that looked too much alike or that lacked the eye-catching styling of their foreign competitors. More and more, consumers also came to see GM cars as being lower in quality and more expensive than the vehicles rolling off the Toyota and Honda assembly lines.

The NUMMI plant in Fremont, Calif., a joint venture between General Motors and Toyota. NUMMI was one of several experiments GM engaged in during the 1980s to learn how to make its manufacturing operations more competitive.

Recognizing that it was losing ground to the Japanese, General Motors made a major effort to upgrade and automate its plants in the 1980s (see *Lesson 1*, next page). The plant improvements were an attempt to lower GM's production costs, an area where it has long lagged behind even its domestic competitors.

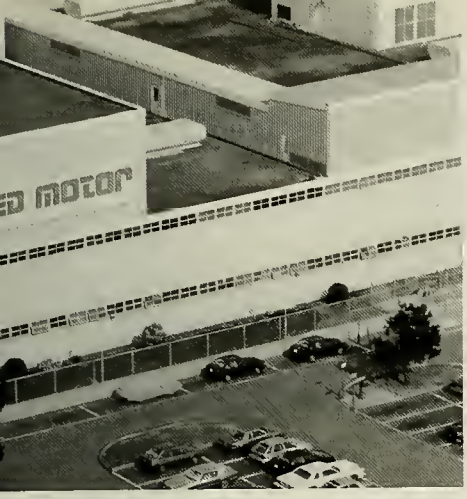
While GM found that automation is important, it learned that other ways of improving productivity (many pioneered on Japanese factory floors)—like keeping minimum inventories of parts on hand, finding ways to involve and empower workers, and becoming committed to the continuous improvement of both products and the manufacturing process—were even more vital.

To learn more about these techniques, GM engaged in several partnerships with Japanese companies during the 1980s (see *Lesson 2*, next page) and launched a new car division, Saturn, to apply these lessons and to develop its own manufacturing innovations.

Even before GM's Dec. 18 announcement, auto analysts were in agreement that General Motors is making good use of the lessons it learned in the decade just past and is beginning to turn the giant corporation around. While it will take time to rebuild consumer confidence lost in the 1980s, car buyers and the automotive media seem to like the high-quality cars GM is putting into showrooms.

Sales of the 1992 Buick Park Avenue, a stylish midsize car, are running about 34 percent ahead of sales of the previous version of the model. The Chevrolet Caprice

The 1992 Cadillac Seville, winner of the top award from three major automotive magazines, is a product of GM's redoubled commitment to making quality cars.



was named *Motor Trend's* Car of Year in 1991, and the new Cadillac Seville has captured top awards from three major automotive magazines. While Japanese makers still earn the top spots on the index of customer satisfaction published by the California-based J.D. Power & Associates, Buick and Cadillac ranked fourth and seventh, respectively, on the most recent list—the only U.S. carmakers to appear in the top 10.

Over the past two years, GM has revamped many of its models and introduced a flurry of new vehicles, including 16 new cars and trucks for 1992—the largest new car rollout in automotive history. These cars are winning consumer approval for their sleek, aerodynamic styling and high quality. In addition, the company is winning a well-deserved reputation as a technical leader in such areas as anti-lock brakes and electric vehicles.

GM has also been at work streamlining its massive organization. Its parts-making divisions have declined from 12 to nine. The division that makes brakes and suspension systems for GM cars is being merged with the one that makes hardware related to those systems. The GM engine and transmission divisions have been merged into a single powertrain division.

And, while GM as a whole continues to lose money, its two major acquisitions of the 1980s—EDS, a computer services company, and Hughes Aircraft—are both doing well. But Stempel acknowledges that there is still much to do. For example, GM is still the highest-cost auto manufacturer and its plants are still not as efficient or as flexible as those of the Japanese.

GM's latest advertising campaign says the company is "putting quality on the road." With 24 other car companies also putting quality—in the form of some 600 models of cars and trucks—on that same road, GM will have to continue to improve the way it designs, engineers and makes cars to remain competitive. The *Journal* asked Robert Stempel what lessons he feels his company distilled from its experiences in the 1980s and how it is using those lessons to meet its goals for the decade ahead. Here are his answers:

LESSON 1

Balance Automation With Well-Trained Workers

In the late 1970s General Motors launched a major effort to modernize its aging assembly and parts plants and introduce robotics and other automation technology to its factories. By the end of the 1980s the corporation would spend about $77 billion on plant modernization.

"Many of our plants were built in the 1920s and 1930s," Stempel says, "and were of a style that was just the way they used to teach at WPI. They had high bays and columns and cranes and so forth—a lot of vertical motion. So, we built new plants and refurbished older ones, because if you're going to be competitive in today's world you need modern, up-to-date facilities."

The new and renovated plants incorporated some of the latest ideas in manufacturing, Stempel says, such as unloading parts and materials near where they'll be used in the plant to minimize trucking and handling, and reducing the amount of room needed for parts storage by keeping just those raw materials on hand that are necessary for the immediate future—what's known as just-in-time inventory. "Most of all, we decided we better be pretty flexible," Stempel says, "because we don't know what the automobile is going to look like in the future, other than that it will probably have four wheels."

While the investment in plant modernization has paid off by giving the corporation a modern manufacturing base, its experimentation with automation has taken longer to bear fruit, Stempel says. "Early in the 1980s there was a feeling that you could do everything with robots—that they would make things quite simple. We've learned over time that you want to automate things that are repetitive or that take a lot of grunt work—things like the precision placement of parts or precision welding. None of us can do the same thing perfectly hour after hour, but a robot can.

"But where you have tasks that may vary from car to car, or tasks that will be constantly changing, don't discount a well-trained worker. The human body is still the most adaptable machine when it comes to reprogramming. So you need a balance of automation and people. That balance is what makes it work."

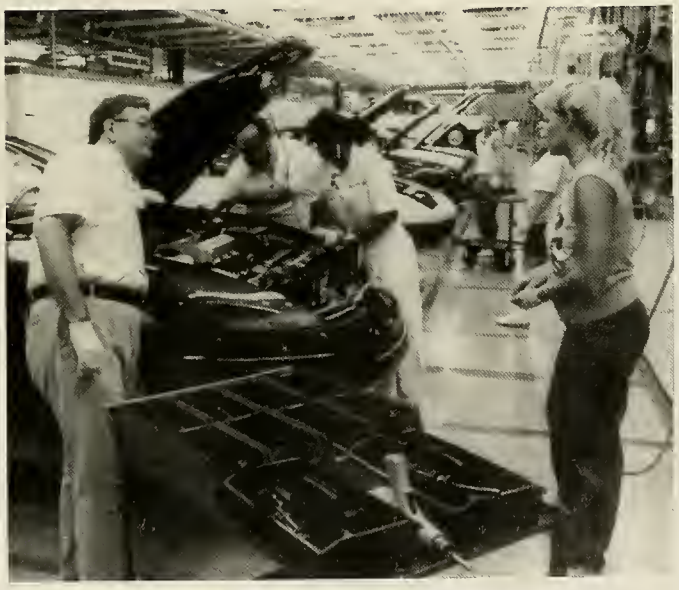
LESSON 2

Make Workers Part of the Quest for Quality

While General Motors worked to upgrade and automate its plants, it also entered into several critical projects during the 1980s aimed, at least in part, at learning why Japanese automakers were able to turn out high-quality cars faster and less expensively than U.S. manufacturers. The most important of these undertakings was a joint venture launched in 1983 with Toyota Motor Sales Co., Japan's largest and most profitable car company.

Called NUMMI (New United Motor Manufacturing Inc.), the company today builds the Geo Prizm, the Toyota Corolla and a Toyota pick-up truck at a GM plant in Fremont, Calif. GM and Toyota each appointed half of the members of the NUMMI board of directors and the plant itself is managed by Japanese and American staffers.

"The joint venture was really a learning laboratory for General Motors," Stempel says. "We wanted to know what the Japanese did differently that we might also try. Was their success due to the fact that they come from a country half-way around the globe, or is it the fact that they



Workers at the modern Saturn plant have been given a substantial role in ensuring the quality of the products they make.

do things differently than we do?"

GM discovered that while automation and advanced technology played a role in Toyota's success, the way it manages its plants and people is far more important, Stempel says. "We learned about just-in-time inventory, about ideas like continuous improvement—even about things as simple as workers using visual signals to let people know when they are running out of materials or when something isn't quite right on the line. Overall, it's been a good learning experience for us."

The techniques employed at NUMMI, including a strong emphasis on human development and placing responsibility for decision making and quality improvement in the hands of hourly workers, would ultimately play a role in the success of General Motor's Saturn Division. Saturn represented GM's attempt to start with a clean sheet of paper and invent, not only a new car, but a new way to design, engineer and build it.

Created over eight years at a cost of about $3 billion, Saturn is the first new GM division since founder William Durant acquired the Pontiac Body Co. in 1916. Stempel says Saturn was designed to acknowledge some fundamental rules about manufacturing that GM had come to appreciate. "You've got to understand that customers today are only going to accept the highest-quality products," he says. "They're looking for something new and fresh and they're looking for something that's done in a short period of time. So Saturn was set up to meet those demands.

"The objective was to build a small, highly fuel-efficient, affordable car here in the United States at a profit. We set some very tough parameters for ourselves, because we realized that if we can't build a small car profitably, it will only be a matter of time before we go out of this business."

The first Saturns went on the market in 1989, and so far the experiment seems to have been a great success. "We've stayed with our goal of having only the highest-quality product," Stempel says. "We've gotten good customer acceptance—it's one of the few cars we have on the market today that's really selling well—and buyers are recommending it to their friends and neighbors."

As it did with the products of the NUMMI experiment, GM is sharing the lessons of Saturn with its other divisions. "We're taking the people training, the educational skills, and the idea of teamwork and applying them. We've been doing that from day one. In some units it's worked very well; in others, where we have more of a history of friction between labor and management, it will take a little longer to get it through the system.

"Sharing these experiences is something we do on a regular basis at General Motors. And we do share both ways. We share where we've screwed up, and we share where we've had successes. It's important to take apart your failures, to say, 'OK, we learned that once, let's not learn it again, guys.' With success we say, 'let's see how many times we can spread that good example in our various organizations.'"

One way GM is spreading the idea of empowering workers is the Quality Network, an agreement enacted between GM and the United Auto Workers in 1987. The agreement says that all GM employees—from the chairman on down—are partners in the process of delivering quality vehicles to customers. Essentially, the Quality Network is a way of sharing the goals of the corporation with all employees and then giving them the

Cadillac general manager John O. Grettenberger tells workers at the Hamtramck plant they've won the 1990 Baldrige Award. Robert Stempel can be seen behind the podium at left.

"We're Going to Walk Throug

WPI NEWS SERVICE PHOTO

Stempel, on campus to deliver the 1987 Commencement address, stops to admire a race car designed by WPI students.

The man who took charge of General Motors on Aug. 1, 1990, has had a lifelong fascination with cars. Born in Trenton, N.J., Robert C. Stempel grew up in Bloomfield, N.J., where he worked in a garage to earn money for college. He later fixed cars for schoolmates while earning his degree in mechanical engineering at WPI.

After he graduated in 1955, he worked briefly for General Electric and served in the U.S. Army Corps of Engineers, but his real ambition was to land a job at General Motors. He began as a design engineer in the Oldsmobile chassis design department in 1958. His first assignment, designing part of a wheel assembly, went poorly, but he learned and went on to develop the front suspension and transmission for the 1966 Toronado—GM's first postwar front-wheel-drive car. Stempel's design for the system that joined the transmission to the front axle is considered a significant engineering achievement.

After earning an M.B.A. from Michigan State University in 1973, he was chosen special assistant to then-GM president Edward Cole. Under Cole, Stempel helped develop the catalytic converter, a revolutionary

Valls For Bob Stempel"

device that enabled GM cars to meet strict government emissions requirements.

Over the next 14 years he held increasingly important positions that exposed him to all aspects of GM's worldwide operation, including director of engineering for Chevrolet, vice president and general manager of the Chevrolet and Pontiac divisions, vice president and group executive of the Buick-Oldsmobile-Cadillac Group, and executive vice president of the overseas and truck operations.

In 1987 he became the youngest GM president in 30 years; three years later he was named chairman and CEO, becoming only the second person since Alfred P. Sloan to hold both the president's and chairman's jobs.

A football player at WPI, Stempel is an imposing 6 feet 4 inches, but he has the warmth and charm to quickly put people at ease. Known for his long workdays, his thorough understanding of cars, and his willingness to take charge in tough situations, Stempel was hailed by GM employees and dealers—and by financial analysts—when he took over the top spot at GM.

Within the corporation, he is known as a fair manager who values loyalty and who likes to manage through teamwork. To encourage participation and debate, he meets with his management team around a round table in his office. He's known for giving credit where it is due, but also for accepting blame when things go wrong. "He's the kind of leader who takes the lumps, and we're going to walk through walls for Bob Stempel," Richard G. LeFauve, president of the Saturn Corporation, told the *Wall Street Journal* last year.

"For several years now we've been focusing on teamwork at General Motors," Stempel says. "As we made the transition to smaller, lighter, front-wheel-drive vehicles, we realized that we had to change 75 years of automotive history and that we'd have to work together to do that. So the sense of teamwork has been building. I've certainly tried to improve communication so we all know what's going on and we can respond in a better fashion to the customer."

Stempel's watch has been marked by some of the greatest challenges GM has ever faced—challenges that began on his second day as chairman, when Iraq invaded Kuwait and sent auto sales sliding. "My first day on the job was great," he says. "The rest of them could have been a lot better."

resources to use their skills and ideas to help realize those goals, Stempel says.

LESSON 3

Serve Your External *and* Internal Customers

The Malcolm Baldrige National Quality Award was created by the Department of Commerce in 1987 to recognize American corporations that have made the greatest strides in improving their quality and customer satisfaction. To qualify for the award a company must do a detailed self-evaluation in seven categories, including leadership, strategic quality planning and human resource utilization. Often, the process of completing this evaluation teaches a company valuable lessons about just where it falls short in the quest for quality.

That's what happened when General Motors' Cadillac Division decided to compete for the award in 1989. "That first year they got into the finals, but they didn't win," Stempel says. "But it encouraged them to go ahead and try it the next year, and, of course, they did win it. [Other winners in 1990 were the Rochester division of IBM, Federal Express and the Wallace Co.] It's been terrific for the work force; they're very proud of it. Today they're building our new Seville and Eldorado, which have won tremendous acceptance worldwide."

What made the difference at Cadillac? While the division adopted many new ideas and procedures aimed at increasing the quality of its products—including many of the ideas discussed elsewhere in this article—one of the most fundamental and beneficial changes it made at its modern Hamtramck Assembly Center was to make its employees aware of their role in the pursuit of quality.

Cadillac adopted the notion of the internal and external customers: the external customer is the buyer of a Cadillac automobile; the internal customer is the next person on the assembly line whose work is affected by how well the previous person does his job.

"If you go through that plant today," Stempel says, "you'll find that everybody understands what quality is and what it takes to make a quality vehicle. That whole work-force training paid off, because each worker knows if he doesn't do his job right, somewhere down the line it's going to cause a problem for someone else."

LESSON 4

Good Manufacturing Begins With Good Design

"With the tremendous number of auto manufacturers today, all offering high-quality products, it's imperative that we increase our competitiveness by getting our costs down and getting our cars to market faster," Stempel says. "One tool for doing this is design for manufacturing or design for assembly. It's a terrific technique."

Essentially, design for manufacturing encourages designers, engineers and production experts to work together at the beginning of the design process to assure that when the car makes its way to the assembly line it can be put together as quickly and efficiently as possible. "It causes us to make our cars with as few parts as possible, and to make sure that there is virtually only one way to fit those parts together, reducing the chances for misassembly," Stempel says. "It's really just good old commonsense engineering. We're using it extensively and it's working out quite well."

The 1992 Buick Park Avenue is one of several new GM models that is easier to assemble, thanks to a technique known as design for manufacturing.

Europe is a Bright Spot, But the Japanese Are Coming

One of the bright spots for General Motors during the 1980s was the turnaround of its European operations—a success in which Robert Stempel played an important role. Today, GM is Europe's fastest growing and most profitable carmaker. With a unified European market just around the corner, the gains the company has made on the Continent over the past 10 years will place it in good position to stay competitive.

Part of the reason for GM's success in Europe was the revamping of its product line to replace boxy, look-alike cars with distinctive and attractive vehicles like the Opel Kadett, the second most popular car in Germany and GM's best-selling vehicle worldwide.

The company also modernized its manufacturing plants and used a heavy dose of synchronous engineering to make its cars easier and cheaper to build. Better relations with union workers in Europe allowed the carmaker to introduce three-shifts-a-day production at several plants, further boosting productivity. As a result, GM's productivity is second only to Peugeot in Europe. As head of GM's Adam Opel unit from 1980 to 1982, Stempel helped introduce the Kadett and also helped build strong ties to labor.

In more recent months, GM has expanded its manufacturing and marketing operations into Eastern Europe and the former Soviet Union, and now has a greater presence on the Continent than even some European carmakers. But to date, GM and its European rivals have not had to deal with heavy competition from Japanese companies. That will soon change, as the Japanese begin to gear up their operations in Europe.

"We're going to have to stay ahead of the game in Europe," Stempel says. "We've had a great learning experience in the U.S., and we'll be able to profit from the mistakes we've made right here. Now we must continue to reduce our manufacturing costs and get even more efficient in Europe. We're not far behind the Japanese in the U.S., but our European operations will have to get leaner without sacrificing our high level of European quality. Yes, we're pleased with our success in Europe, but we're not resting on our laurels."

Stempel says nearly all GM designers have been trained in design for manufacturing and several new GM cars have benefited from the technique, including the new Cadillac Seville and the Buick Park Avenue. The 1992 Seville, for example, has 50 percent fewer parts in its front and rear bumper systems than its predecessor. With fewer parts, cars go together faster and less expensively, a benefit GM is keenly aware of. A company study in 1989 found that 41 percent of the difference in productivity between a GM plant and a comparable Ford plant was due to differences in design.

Cost saving is not the only benefit of simplifying design, Stempel says, noting that, in general, the simpler the design the more reliable and durable the product. He says this new approach to design has made particular inroads into the manufacture of the electronic systems that control emissions on GM vehicles.

"Some of the systems found in cars today are very complex, with many devices, computers and associated wiring," Stempel says. "We've tried to simplify the design, and yet maintain all the controls. With less complexity, we've increased the reliability. But more important, a simpler system lends itself to more precise control of emissions and better fuel economy. It's not by accident that we are the fuel economy leader."

Good design is also enabling GM to streamline the number of unique parts it uses in its cars. For example, it is reducing the number of GM engine families from nine to five, trimming its ignition systems from seven to three and combining some of its 19 platforms (the metal framework on which a car is built).

LESSON 5

Integrate Design, Engineering and Manufacturing

For many years, GM looked at design, engineering and manufacturing as independent functions to be performed in series. As Charles M. Jordan, GM's vice president for design, told the Canadian magazine *Maclean's* last year, "We used to design a car and then throw it over the fence to the engineers. After a while, they would toss it back and say they couldn't do this or that. Then, after a few more rounds, we would both toss it over the fence to the manufacturing guys, who would raise a whole new series of objections."

As a result, General Motors was taking far too long to bring new cars to market, Stempel says. "It used to take us on the order of 60 months—five years—to go from concept to showroom floor," he notes. "Today, most of our cars are coming to market in 36 months or less. The best of the Japanese companies, we find, are doing it in about 27 months. We're continuing to work on this process—we've gotten cars out in as little as 34 months."

Stempel says the time from concept to marketable car has got to be less than three years if customers are to perceive new cars as fresh and exciting. To accelerate its speed to market, GM has adopted synchronous engineering, which essentially means bringing the designer, industrial engineer and production engineer together at the beginning of a new car project. GM has gone a step farther and brought the workers who will actually assemble the car into the initial planning process, an idea that came out of the Saturn program.

Saturn assembly workers have been given a say in many matters previously reserved for senior management—things like the layout of the factory floor, the choice of dealers, and even the selection of the company's national advertising agency. Stempel notes that Saturn workers visited

The body panels of the Saturn are put on last, making it easier for workers to assemble the car's interior.

When it is put on the market later this decade, GM's Impact will become the first modern electric car manufactured by a major automaker. Impact will be built by the highly skilled work force at GM's Lansing (Mich.) Craft Centre.

the vendor contracted to build the machines used to assemble the car's underbody. "As a result of their input," he says, "the equipment is more worker friendly: there's less lifting, turning, stooping and so forth. If a guy's been putting cars together most of his life, he's got ideas about what makes things easy and what makes them harder. It's really worthwhile listening to him."

Synchronous engineering reduces surprises when a new car reaches the assembly line, Stempel says. "If you know you're going to use a weld gun that needs a certain amount of access, you can design that access into the body. If you know you're going to have an operation that requires lifting from underneath the vehicle by an automated system, you can design in the proper clearance or put in special brackets.

"You may even want to change the way you build things. At our Opel facility in Germany, we use what we call a cockpit load, where the assembly that includes the instrument panel, heater, steering column and so on is built outside the car and put in fully assembled. By eliminating the need for workers to do tedious work while lying on their backs inside the car, you reduce mistakes. This idea came about because process engineers were there at the design stage."

Integrating design, engineering and production can help make manufacturing facilities more flexible and better able to respond quickly to the changing marketplace. At its highest level, flexibility means being able to build several different vehicles on the same line, switching effortlessly from one to the other, but it can also mean making several versions of the same car with a minimum of equipment.

On the Saturn assembly line, for example, the same equipment can be used to make either automatic or manual transmissions because, though the transmissions share only some parts, all of their parts were designed to be handled by the same machines. This saves about 60 percent of the cost of building transmissions on two different lines. Similar thinking went into the design of the engine line, where of 86 workstations, 50 are common to the single-overhead-cam and dual-overhead-cam versions of the engine.

At the Cadillac Division, the idea of synchronous engineering was expanded into a more comprehensive management technique called synchronous organization. In this approach, all parts of the manufacturing enterprise—human resources, financial management, design, engineering and manufacturing—are integrated. The goal is to identify the parts of the operation that drive the cost of production, and then eliminate those that add no value to the product.

LESSON 6

Quality is What the Customer Says It Is

In his opening remarks to the third National Quality Forum in 1988, then-GM president Stempel provided a simple definition of quality: "responding to the voice of the customer—meeting his desires and requirements." Chairman Stempel says he is still committed to that definition.

"If a customer is looking at one of our automobiles and he says, 'Well, you know that isn't really a good fit and this doesn't look right to me,' the fact that I can show him a whole raft of data showing that our car is just as good as anyone else's is irrelevant. He said he didn't like it.

"To make products that hit the mark, you have to listen to the voice of the customer. When a customer walks up to our new Park Avenue, LeSabre or Bonneville, his first reaction is, 'Wow, what a car.' He's made a visual assessment. He's seen that not only is it an integrated design that looks good, but the fits are good. When he gets in it and it starts and runs well, then we've got him interested. So, you really have to work to listen to what the customer is saying about your products."

To stay on top of evolving customer demands, GM employs the Continuous Automotive Marketing Survey. At regular intervals after a car is bought—starting soon after the purchase and continuing through the fifth year of ownership—GM surveys the owner and asks how well the car is meeting his or her expectations.

Customer surveys also enable GM to fine-tune its cars once they're on the market, Stempel says. "For instance, a couple of years ago, owners told us that the legibility of the instrument panels in our trucks suffered in strong sunlight or at certain angles. We made changes and polled customers again to see if they were satisfied. Obviously, you want to catch as many of these things as you can during pretesting, but there's nothing like going after the person who's bought a car or truck to find out what he likes and dislikes."

LESSON 7

Break Out of the Boxes

One of the lessons of synchronous organization is that it's no longer good enough to be just a good designer or a good industrial engineer or a good production person. Manufacturing professionals must be prepared to cross the lines between disciplines and learn how their jobs affect every part of the operation. They must be ready to give up the comfortable, insulated boxes they've worked in for so long, Stempel says.

"Some people put an awful lot of emphasis on particular disciplines," Stempel says. "I put a lot of emphasis instead on education. It doesn't matter whether you're an engineer, a physicist, a chemist or a financial person. All of those disciplines have a place, but every one of them begins with a fundamental education, training and logic in the way you do things.

"There are no more one-man bands. I can't run General Motors by myself. It takes the coordinated effort of a lot of people. Perhaps it was my education at WPI, but somewhere along the line I learned that you must depend on others—that you're going to need the skills of others—so you must learn to bring out the best in people. That's what you have to do today.

"This business is complex, whether you're looking at it as a financial analyst, or whether you're looking at it as an engineer," Stempel adds. "Success depends on more than one man and more than one discipline. You've got to manage all of those disciplines in a cohesive manner to bring out the best in the organization."

The New Wave in Manufacturing

By Carol Campbell

More and more, manufacturing companies are discovering that the key to quality and competitiveness lies in unleashing the hearts and minds—and not just the muscles—of their employees.

Once, the twin targets of productivity and profitability were the major concerns of manufacturing executives everywhere. The bottom line was simple: find ways to make products more quickly and less expensively than the competition. In the 1970s and early 1980s, automation seemed the best hope for reaching those targets and gaining a competitive edge. With the proper programming, it was thought, robots could do just about any job better and cheaper than human workers, saving companies time *and* money.

Today, while automation continues to play an important and ever-growing role in industry, manufacturing managers have learned that robots will probably never truly take the place of people on the factory floor. Instead, driven in large part by the success of their overseas competitors, especially the Japanese, American manufacturers are turning more and more to techniques aimed at empowering their employees and unleashing their potential.

The techniques go by a variety of names, but they share a common purpose: making workers true partners in the pursuit of competitiveness. Increasingly, competitiveness itself is being redefined, for most manufacturing executives now agree that a successful company must do more than simply make products faster and cheaper; it must be able to anticipate and meet the constantly rising expectations of consumers.

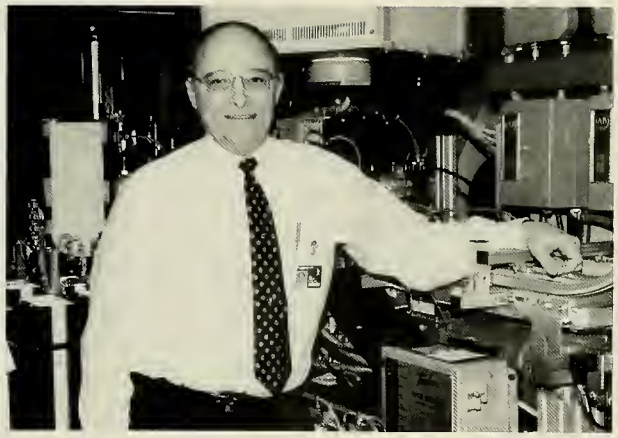
Where once corporations tended to look at workers as interchangeable, often disposable cogs in the manufacturing operation, today they are valued as individuals with a wealth of talent, insight and creativity that can be harnessed to help design and build quality products. In this brave new world, where quality is king, even the traditional relationship between management and labor is being replaced with a new model. Today, managers are likely to join their employees in quality circles and manufacturing cells to work cooperatively to refine and continually improve the way their companies make products.

In the following pages, seven alumni employed as manufacturing executives at major American companies talk about how those firms are riding this new wave in manufacturing.

Carol Campbell is a free-lance writer living in Sturbridge, Mass.

The Image of Quality at Polaroid

Ronald P. Klay '64
Manufacturing Program Manager
Polaroid Corp.
Waltham, Mass.



Ronald Klay shows off some of the advanced automated equipment used in the manufacture of film at Polaroid.

Polaroid, the leader in instant photography since it introduced the Land Camera in 1948, is constantly tracking the evolving demands of consumers to assure that its products are in tune with them, according to Ronald Klay. "We want to deliver quality products based on the perceptions and needs of the consumer."

Klay is currently in the midst of a project that involves managing the development of a new instant camera and film system from the concept stage through design and manufacturing. Code-named "Joshua," Klay says the product will go on the market later this year.

As part of the Joshua program, Polaroid is using a new approach to product development that calls for the entire process to be supervised by the same management team, he says. This team approach has carried over to the manufacturing floor, where workers have been organized into work units responsible for understanding and managing the entire manufacturing process.

"Sometimes there is resistance to change like this," Klay says, "but generally people are willing to try new ways of doing things. They're seeking a feeling of ownership in the products they make and some influence in the decision-making process. This is what we hope to make possible through the team concept approach."

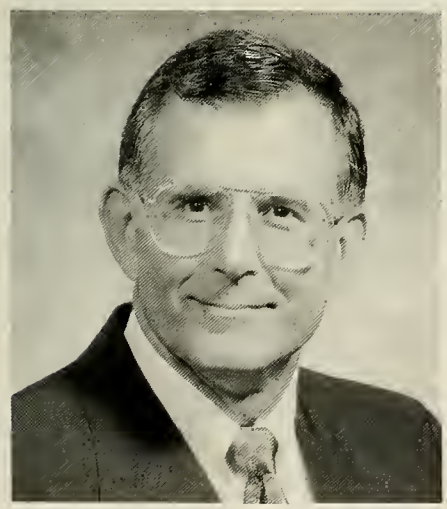
To get the process under way, Klay says he has had to successfully integrate employees from several of Polaroid's operating units. "When a team is established," he explains, "a significant adjustment and training period is required. The employees are reoriented to their new jobs, and managers who have not had direct involvement in manufacturing find themselves actively engaged in operational concerns related to assembly."

Klay says the film manufacturing operations, for which he is directly responsible, will make significant advances in manufacturing technology. "With the use of sophisticated management information system (MIS) software, we will monitor the consumption of raw materials and the system performance in real time," he says. "The assembly process will be fully controlled by computers and will be operated as a modular system. Essentially, that means that each major operation will operate independently of the others, but be interconnected by computerized conveyors. Should one part of the line have to stop, the others will continue, with partly assembled product being placed temporarily into in-line storage until the affected operation resumes."

The assembly process will also make use of a monitoring system called a vision analyzer. The analyzers, developed by a Needham, Mass., company called Cognex, record images of the product at key points in the assembly process and convert them to digital information. The digitized images are then statistically analyzed to evaluate how closely the product falls within predetermined control limits. Processes that fall outside these limits are immediately corrected, greatly increasing the consistency of the end product.

Klay joined Polaroid as a production supervisor in 1971 after working as a manufacturing engineer at Texas Instruments in Attleboro, Mass., and serving as president of and a partner in South Shore Metal Products Inc. in Braintree, Mass. He was named manufacturing manager in 1982 and recently became manufacturing program manager.

Klay says Polaroid is actively restructuring all of its design and manufacturing capabilities to take advantage of the benefits of the team concept. "The bottom line is quality in both product consistency and photographic performance," he says. "I think the team approach we've implemented with the Joshua project, as well as the advances in manufacturing technology we've made, go a long way toward meeting that objective."



Improving Quality with People Power

William C. Zinno '63
Vice President of Manufacturing
Miller Electric Manufacturing Co.
Appleton, Wisc.

Those close to manufacturing operations recognize that the work force is changing," William Zinno says. "Today's production workers want more say in the decisions that directly affect them. We managers also want to involve more employees in the decision-making process. We want them to bring their minds—as well as their hands—to their jobs."

To do so, Miller Electric, whose products include electric arc-welding power supplies and related equipment, is in the midst of a pilot employee empowerment effort it launched in 1990. Under the program, the company has organized production workers into a manufacturing team consisting of a production coordinator and about 75 employees, all focused on producing a single product line. The group acts as a self-managed business unit, determining its own staffing, scheduling and so on.

The team uses a consensus approach to determine whether or not changes need to be made in the product or in the processes

used to manufacture it, Zinno says. "While the decisions may sometimes be a bit slower in coming, they are usually much better than those made by a single individual, and people are committed to them."

Zinno says Miller's pilot manufacturing area is deliberately compact. "The group's final assembly line builds just what is needed each day, which drastically cuts the amount of inventory and the lead time normally needed to manufacture the products."

Before the business unit approach, the assembly line operated in a traditional manner, with items assembled in several steps by separate groups of workers in different locations. For example, to make electric transformers, one group would wind the coils, a second would crimp the ends, a third would assemble the coils into magnetic cores, and a fourth would do the required welding of the transformer assembly.

Within the business unit, every worker is trained to do many jobs, and the team as a whole is responsible for getting the product made. This cross-training enables workers to switch operations according to the changing work load on the assembly line, which makes the manufacturing process more efficient and responsive. But even more, Zinno says, because workers are so thoroughly involved in the product, they feel a greater sense of responsibility for and commitment to its quality.

"Workers can better see how their jobs affect the end customer," he says. "Another advantage of this approach is that employees become intensely dedicated to the company because of the freedom we allow them to have in their jobs."

Zinno, center, listens to a briefing by a member of a manufacturing team, part of Miller Electric's employee empowerment program.

Miller Electric was founded in 1929 in the basement of Niels C. Miller, who made one of the first direct-current welders and began by selling the devices to local blacksmiths. Today Miller's descendants run an international enterprise that employs more than 1,600 people. The company's primary customers are distribution networks for welding supply companies who, in turn, sell equipment to end users such as fabricators and body shops. Miller's competition comes largely from three domestic manufacturers, who sell to many of the same distributors.

"There is fierce competition in the cost and quality of the product," Zinno notes. "The challenge is to run with less inventory and lower production costs, while at the same time maintaining a primary focus on improving quality."

By looking at its manufacturing operations from the perspective of its employees, Miller hopes to achieve the kind of world-class quality it needs to make its products stand apart from those of its competitors, Zinno says. "To make improvements in our products and processes, Miller has always focused on people rather than things. We will continue to follow that philosophy in the years to come."

Prior to coming to Miller in 1990, Zinno was vice president of manufacturing at the Turbo Products Division of Dresser Rand in Olean, N.Y. In his present position he handles all plant operations, including assembly, fabrication, production control, maintenance, and plant engineering. "What has made this job truly exciting for me is the opportunity to branch out and develop this pilot employee-empowerment process," he says.

Zinno says the pilot program, which he describes as promising, is continually improving and maturing. He says the company plans to expand it throughout its manufacturing operation in the months ahead.

Gearing Up To Make a Medical Wonder

Christine Powers '75

Director of Manufacturing
Biopure Corp.
Boston, Mass.

You've been involved in a car accident and you've lost a lot of blood. As emergency crews work to stabilize your vital signs, you begin to go into shock. At one time medical technicians may have had few options other than wrapping you in a blanket and keeping you comfortable until you reached a hospital, where doctors could do a transfusion to replace the lost blood volume and get oxygen to your cells. In the future they'll be able to do more, thanks to researchers at Biopure Corp., makers of a hemoglobin-based blood substitute that can be administered on the spot through a simple injection—without the need for cross-matching of blood types.

For Boston-based Biopure, a biotechnology firm that has until now been involved strictly with research and development, the production of this new product will mark its first experience with manufacturing, notes Christine Powers, who is responsible for Biopure's manufacturing operations.

Powers examines a sample of Biopure's first product, a blood substitute.

Before joining Biopure, Powers worked as a process engineer for Clairol Inc. and Armor-Dial Inc. She later joined Baxter Travenol Labs Inc., where she ultimately became a product manager. "I was lured to Biopure in 1989 by the start-up opportunity—by the chance to build an organization that I believe is necessary," she says.

Having hired most of Biopure's 16 manufacturing employees (the company, founded in 1984, currently employs 81 people), Powers is now training them to work within the constraints of a pharmaceutical manufacturing environment and to adhere to strict Food and Drug Administration (FDA) regulations. The company has already initiated the first part of a three-part FDA review to determine the safety and effectiveness of Biopure's first product in humans. Previously, the company performed a lengthy series of tests on animals in support of this submission.

In addition to humans, animals will also benefit from the new product. In fact, Biopure will become the only company to market a blood substitute to veterinary clinics. The market for the product in human medical treatment, on the other hand, will be far more competitive, Powers says. For this reason, the company has signed a strategic agreement with Upjohn Co., which will handle all marketing and distribution for the human product in the U.S.

Powers says the production process used to make the blood substitute, developed at a pilot manufacturing facility in Boston, begins with the product's raw material—blood from slaughtered cattle. The red blood cells are separated and broken open, so their hemoglobin can be recovered. The hemoglobin is then refined in a patented process that includes an extensive purification step.

Of particular importance is a filtration system that separates the blood before it is purified, Powers says. "This process allows us to produce large quantities of the product at a relatively low cost," she adds.

Because the entire operation is carried out in a controlled environment, workers must wear "bunny suits" that completely cover their bodies, Powers adds.

Current plans call for the animal product to hit the market in 1993, with the human product to follow in 1994 or 1995. Powers, who says she is confident that the new product will receive a positive response in both of its markets, is currently preparing the company for a comprehensive effort to gear up its production facilities to meet the anticipated demand.

A Focus on People Issues at Du Pont

David F. Gilbert '54
Manufacturing Resources Manager
Du Pont Co.
Wilmington, Del.

Founded in 1802 to make gunpowder, Du Pont today is a $40 billion operation that manufactures a host of products, including chemicals, synthetic fibers, electronics and polymers. Each of the company's seven principal business sectors, as well as Du Pont's Conoco subsidiary, could constitute a *Fortune* 500 company in its own right.

David Gilbert, with Du Pont for 37 years, joined the company's engineering services division field program just after completing his military service in 1956. This training program was attractive, he says, because at the time he wasn't sure what he wanted to do in his career. Over an eight-year period Gilbert worked on assignments in four locations, gaining experience in engineering development, research, new processes and management.

Deciding upon the management route, Gilbert transferred out of engineering into an industrial department and now works in the chemical manufacturing division of the chemical sector. Over the years he has held a variety of supervisory positions, including plant manager at four locations and technical consultant in a joint venture with a Japanese company.

In his current post he serves as a resource for the manufacturing staff at all 28 of the chemical sector's manufacturing sites, handling personnel matters and serving as a representative to various other departments. While many of his challenges involve employee safety and environmental awareness (Du Pont boasts the lowest injury rate in the world and is the leader in the elimination of ozone-damaging fluorocarbons from refrigerants and solvent products), he says Du Pont has, over the last 10 years, turned its attention more and more to the "people" aspect of running the corporation.

Like so many other companies, Du Pont is trying to break down the rigid corporate hierarchy in favor of a total team approach. Gilbert says there is an effort to remove layers of management, while maintaining strong employee motivation.

"We're working harder at including all levels of employees in the business aspects of our operations," Gilbert says. "By sharing more business information with employees and increasing their involvement with our customers, I think we've made our employees feel they are more 'in on the action.' I think they also have a better appreciation of how they can add value to our business effort."

He acknowledges that the breakdown of traditional management roles has created a new problem—how to assure that workers can still advance within the corporation and be recognized for their individual contributions. Gilbert says Du Pont's management teams are working to support the greater contributions of employees through increased recognition and rewards.

Du Pont wants to more fully involve employees at its 28 chemical manufacturing sites in the operation of the company.

Du Pont's David Gilbert.

"At our operating sites, plant managers have been given more authority to identify and reward employees and teams for their value-added contributions," he says.

Diversity is another key focus at Du Pont today, Gilbert notes. "We are a global company with a whole range of cultures represented in our people," he says. "We're learning to appreciate the value of this diversity and to utilize the best inputs of all our people in our business."

Another "people issue" receiving increasing attention at Du Pont, Gilbert says, is the recognition that a successful career does not necessarily have to lead to a position in management. "When I was coming up in the organization, it seemed that the managerial route was the best way to advance. Now I feel Du Pont has established the technical or professional *and* the managerial routes as ways to motivate and reward contributions. One of the values of this is you don't end up creating poor managers out of outstanding technical or professional people."

Raising Standards by Raising Awareness

Stuart C. Kazin '61
Vice President of Manufacturing and Distribution, Worldwide
Lotus Development Corp.
Cambridge, Mass.

When Lotus Development Corp. made its debut in the computer software world in 1982, it quickly became a leader in application software packages. Within four years the company was a $225 million multinational corporation whose major product, Lotus 1-2-3, had become the all-time best-selling personal computer software product.

However, intense competition among makers of personal computer software over the past decade has shrunk the effective life span of new products to less than a year, on average, increasing pressure on publishers like Lotus to upgrade their software as quickly and efficiently as possible.

To retain its position as a leader in software development, Stuart Kazin says Lotus is currently developing a new type of product called "groupwear," which is designed to facilitate communications within a company. The products will include *Notes*, which will allow an entire company to access information in a single database at the same time, and *CC:Mail*, an electronic mail system developed by a California company acquired by Lotus.

Kazin says he spends a great deal of his time traveling between Lotus' Cambridge, Puerto Rico, Dublin, and Singapore manufacturing locations, where he strives "to build strength from the inside out." High on his agenda these days is diversity-awareness training.

Kazin and his staff have identified a need to draw employees closer by having them acknowledge their differences and the potential to use those differences in a positive manner in product development. To do this, Lotus hired consultants who trained selected staff members in diversity awareness. These staff members now supervise three-day workshops that focus on stereotypes, beliefs and diversity, among other topics. More than 500 of Lotus' 2,000 U.S. employees have completed the training, and Kazin says he has already seen improvements in energy levels, quality of performance, and business orientation.

Lotus' Stuart Kazin.

Kazin's background includes a master's degree in aeronautics and astronautics from MIT, a stint as general manager of the Precision Measurement Division of Dynamics Research Corp. in Wilmington, Mass., and a job as general manager of the analytical division of Foxboro Corp., a maker of process-control systems. He joined Lotus in 1985 as director of manufacturing and distribution and was named a vice president in 1988.

Manufacturing at Lotus means making duplicate copies of software products on disks—100,000 disks a day—and packaging them with written documentation into boxes that are then shrink-wrapped. While the manufacturing process is fairly conventional, Kazin says he hopes to improve productivity through the use of diversity-awareness training.

He says he also plans to build on the positive outcomes of the awareness training by forming a cross section of Lotus workers into Corrective Action Teams (CATs). The CATs will draw on the knowledge of individuals from different segments of the manufacturing field to attack and quickly solve any customer problems or concerns. The solutions to those problems will be incorporated into the next generation of software products. Kazin says this "systematic quality-improvement process," for which the CATs will be responsible, is essential in today's competitive software industry.

"Your definition of quality must be based on customers' requirements," he says. "When these requirements are not met, you vigorously solve the problem and solve it forever. When mistakes are made, I like to see them be 'innovative mistakes.'"

A worker adjusts equipment that copies computer disks at Lotus' manufacturing facility in Cambridge, Mass. The company produces 100,000 disks every day.

Bringing Automation to The Oil and Gas Industry

William U. Pursell Jr. '59
Vice President of Manufacturing
Camco Products and Services Co.
Houston, Texas

Pursell, at right, and two workers examine an automated turning and milling machine, part of Camco's modern FMS facility.

Camco supplies a variety of production and safety equipment used in oil and gas wells, most of which are located offshore. Competition among manufacturers of this equipment has become especially fierce in recent years, according to William Pursell. In response, he says, Camco has turned increasingly to automation.

For some of its processes, the company has been a major innovator of manufacturing systems that employ automatic turning and milling machines, which have built-in chuck jaw changers, tool storage, and measuring devices. The machines are supported by robots that load and unload parts, by coordinate measuring machines, and by two automatic guided vehicles (AGVs) that move parts about the plant.

"This automated equipment is arranged into cells in our new factory," Pursell says. "The AGVs carry parts from the machining operation cell to the coating and audit inspection areas, and then return them to the machining cells. We call this our flexible manufacturing systems or FMS shop."

The market in which Camco competes is changing, Pursell says. "Where once customers were concerned primarily about quality and performance," he says, "the market is now quite price sensitive, though customers still demand high quality in our products. Camco is a customer-driven company. Our objective is to meet our customers' requirements with a reasonable return to our investors."

The equipment and systems employed in Camco's FMS shop enable the company to make its products economically in small lots. For example, Pursell says, because they can quickly switch between various tools and processes, the milling and turning machines can make all the machined parts needed for an assembly in one session. "This results in shorter delivery time and reduces the amount of work we have in progress," he notes.

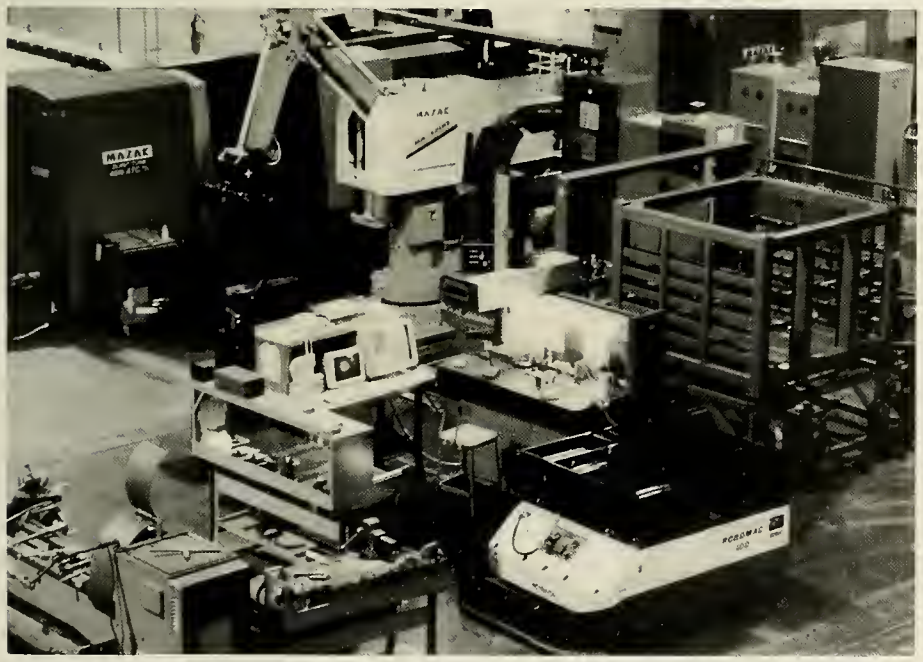
Pursell says automated systems like this will be the key to the future success of companies like his. "The bottom line here is profitability," he says. "Automation will enable us to lower our costs and become more competitive overall."

Pursell's expertise in manufacturing comes from 30 years of experience in the field. He began his career in 1962 as a project engineer at SKF Industries Inc., makers of ball and roller bearings. He became a plant manager before leaving in 1973 to join Reed Tool Co. in Houston as materials manager. He also worked briefly for Hydril Co., producers of premium threads on production tubing used in oil and gas wells, and for Hinderliter Energy Equipment Corp., fabricator of wire-rope sheaves, traveling blocks for cranes, and low-pressure well heads.

At Camco, Pursell is responsible for plant maintenance, purchasing, manufacturing engineering, materials management and the "direct-hour" employees who run the machines. When Camco hires, he says, it looks for highly skilled and well-trained workers, as well as degreed mechanical and electrical engineers with expertise in manufacturing. "These qualifications add a degree of sophistication to our manufacturing talents," he says.

Pursell says Camco is currently reviewing its entire manufacturing process—from quotations to shipment—with an eye toward reducing cycle time. "Innovations such as modular product drawings, paperless operations, multifunctional task teams, and work teams on the shop floor are all helping us achieve our goal of shorter lead times," he says. "Automation of not only the manufacturing process, but of our communications systems will be vital to achieving that goal."

He notes that Camco is also implementing the concept of factories within factories. "These individual operating units will have their own resources and their own work



Some of the components of Camco's flexible manufacturing systems (FMS) shop can be seen in this photo: at top, left, the turning and milling machine; at top, center, a robot that loads and unloads parts for the machine; and at bottom, right, an automatic guided vehicle that moves parts around the plant.

teams, which will focus on meeting our customers' requirements, as well as on reducing the cost of parts and improving our quality. All employees within these factories within factories will be assigned to one of these teams."

The team approach is part of Camco's total quality management program, aimed, Pursell says, at meeting customer requirements by getting all employees involved in the process of improving quality. In addition, Pursell says the company is currently developing a strategic quality plan "that will serve as an umbrella for all of our operations. We've done well despite the ups and downs of the market. We now have a new set of challenges facing us. By streamlining all our manufacturing operations, we will meet these challenges and build on the qualities that have made us successful over the years."

Learning from the Pioneers at Clairol

Richard R. Nabb '73
Vice President of Manufacturing
Clairol Inc.
Stamford, Conn.

Drawing on the ideas of quality pioneers W. Edwards Deming and Philip Crosby, Clairol has embarked on an innovative quality management program, Richard Nabb says.

According to Richard Nabb, the market for consumer hair care products is becoming more competitive all the time. Clairol, a subsidiary of Bristol-Myers Squibb Co., has long been a market leader with familiar brands like Miss Clairol, Quiet Touch, Loving Care and Final Net. Today, though, Nabb says Clairol is looking for new ways to hold on to that lead.

"Consumers are not as loyal to brand names as they were 10 years ago," he says. "Today they can choose from among many similar versions of the same product, so they look to get the most value for their money. Before they buy, they also consider factors like ease of use, environmental friendliness, and the number of applications per package."

Nabb, a 19-year veteran with Clairol (he held a summer job with the company in 1972, while pursuing his degree in mechanical engineering at WPI, then joined the company full time as a production supervisor after graduation), oversees packaging, engineering, processing, packaging materials and purchasing for Clairol.

Until recently he also handled warehouse and distribution operations. In an effort to gain consistency and improve productivity, Clairol consolidated the warehouse, distribution, financial, and customer service operations of its consumer product group with those of the Bristol-Products and Drackett divisions of Bristol-Myers (which make such health-care products as Bufferin and Nuprin and such household products as Windex, Draino and Renuzit).

Recently, Nabb says, Clairol has begun to focus on issues related to technology and human resources in an effort to increase its competitive edge. "With 70 percent of our product assembly and packaging processes handled by machinery, we want the manufacturing process to work as smoothly as possible," he notes. "To do this we must pay careful attention to the design of our packages and equipment. In particular, we must consider whether these designs make good use of the capabilities of the manufacturing process as it operates today, and anticipate rapid changes in manufacturing technology. A design is useless unless the technology exists or can be developed to back it up."

One new type of manufacturing technology Clairol is evaluating for its packaging lines is the vision system, a camera that checks products for defects at various stages of the assembly process. The system can also spot potential jams in the flow of partly assembled products and then stop the process automatically. "The Japanese call this "Jidohka" or auto-*no*-motion," Nabb says.

Nabb says Clairol is currently using a computer system that tracks weights, torque and productivity during the assembly of containers of liquid products, like shampoo, hair color and fixative, to verify that they are being filled and packaged properly. The system reduces the number of containers that must be rejected at the end of the process because they do not meet customer requirements.

Before the computerized control system was installed, the weight checks were tracked manually, which was inefficient. The computer is also much more accurate than manual weighing, Nabb says, and allows an operator to anticipate problems and take corrective action, which further reduces errors.

Drawing on the philosophies of quality pioneers W. Edwards Deming and Philip Crosby, Clairol is adopting an innovative quality management program. At the heart of the program, Nabb says, is an effort to invest in Clairol's shop-floor employees by providing them with additional training and by raising their educational levels. For example, through the company's Quality Skills Enhancement Program, workers can improve their reading and math skills.

The quality management program is an outgrowth of Clairol's Quality/Productivity Improvement Process or Q/PIP. Through training and education, the program encourages workers to become thoroughly familiar with their jobs and with the processes to which they contribute. Q/PIP also seeks to make the workplace a "quality culture" by teaching workers to embrace diversity and engage in cooperative problem solving.

Q/PIP is an alternative to traditional approaches to management, which Nabb says "are not effective methods to manage change in the current marketplace." Under the program, senior managers at each work site are given responsibility for one or more of Philip Crosby's steps for implementing a quality improvement process. These include measuring quality, setting quality goals and communicating them to employees, fostering employee education, and striving for zero defects. Managers are responsible for analyzing and improving the procedures and systems at their sites that play a role in total quality management.

According to Nabb, Clairol will undergo a complete corporate changeover during the next few years as Q/PIP is fully implemented. For example, managers will no longer simply delegate work to employees; instead they will become leaders of work groups that will solve problems cooperatively. Developing its employees and giving them the responsibility to work together to improve productivity and quality will ultimately give Clairol the competitive edge it seeks, Nabb says. "The company that can get and keep the best and the brightest will be the winner."

JOHN REIS

FLIGHTS OF FANCY

Throughout history, architects have enjoyed adding distinctive flourishes to their designs, personal touches that add nothing to the structure or function of a building, but which enhance its visual appeal. Such embellishments as statues and gargoyles, decorative cornices and portals, ornamental stonework, and multicolored patterns of brick help make structures more pleasing to the eye, give them a sense of drama, importance or even whimsy, and give each building a unique identity.

While the popularity of ornamentation waned during the middle of this century — a period that gave us the sleek but sterile glass tower—building designers are again letting their imaginations run free and are accenting their creations with sometimes unexpected splashes of color, texture and form.

At WPI, some bits of architectural ornamentation are enjoyed by even casual observers—the arm and hammer weather vane on the Washburn Shops, for example, or the giant concrete seal on the north face of Goddard Hall. Others, such as the statue of Minerva atop Sanford Riley Hall, often go unnoticed. In these pages we present a sampling of flourishes and embellishments that give the WPI campus a look all its own.

KENNETH McDONNELL

Making an Entrance

Noted architect Stephen Earle designed Salisbury Laboratories 20 years after the completion of Boynton Hall, also his design. He was asked to create a solid, functional laboratory building to house the college's science departments. Earle fulfilled his charge, but allowed the artist within him to break loose here and there in the otherwise austere design. A close look reveals how the architect gave various functional elements a quiet beauty through simple embellishment, such as in this arched brownstone portal adorned with a terra-cotta Institute seal. Salisbury Labs was the gift of Stephen Salisbury III in honor of his father, the first president of the Board of Trustees.

JANET WOODCOCK

Clear Artistry

Alden Memorial, currently undergoing an extensive renovation, is considered by many to be WPI's most attractive building. Named for George I. Alden, the college's first mechanical engineering professor and a founder of Norton Co., the building was a gift of the George I. Alden Trust. It is heavily embellished—inside and out—with ornamental stone carvings and hand-carved woodwork. A series of 27 stained glass window medallions in its great hall tell the story of American history, starting with the early days of exploration and settlement and ending with the inventive genius of the likes of the Wright Brothers and Samuel F.B. Morse. These medallions were designed by Wilbur H. Burnham, whose work can also be seen in the National Cathedral in Washington, D.C.

ROGER N. PERRY, JR. '45

Blowin' in the Wind

The weather vane on the Washburn Shops tower is not the same arm and hammer that adorned the building when it was completed in 1868. The original, fashioned from a sketch made by Charles Morgan, then superintendent of Washburn and Moen Co. and later founder and president of Morgan Construction Co., was stolen in 1975, probably as a student prank, and was never returned. In 1978 a contractor working on renovations to Washburn commissioned a metal worker to make a replica based on photos of the familiar landmark.

Medieval Athletes

The grotesques that circle Alumni Gymnasium, seemingly engaged in a variety of sports, are the work of Harry T. Easton, a sculptor who specialized in building embellishments. Many of his stone carvings, including the gargoyles, door and window frames, and steps of Alumni Gym, were carved from limestone quarried near his home in Bedford, Ind. According to Easton's son William, he had a whimsical streak common to many medieval sculptors; he liked to incorporate the faces of his clients into his work, although no records exist to indicate whether the Alumni Gym gargoyles were modeled on the faces of former faculty or staff members.

JOHN REIS

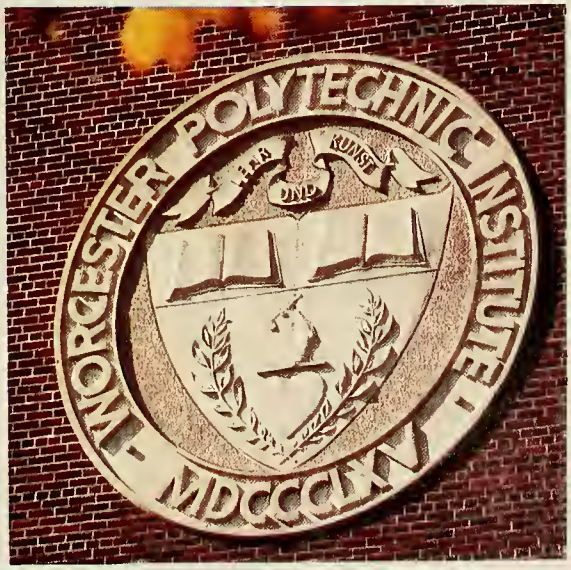
The Goddess of Sanford Riley

This statue of Minerva, the Roman goddess of wisdom, sits high atop the roof of the college's first residence hall, watching over the occupants of this Tudor-style building. The statue was the gift of the alumni of R. Sanford Riley's old fraternity, Sigma Alpha Epsilon. Riley, a member of the Class of 1896 and president of Riley Stoker Corp., died in May 1926, shortly before he was to be elected to the WPI Board of Trustees. The statue, which served as a finial to the completed building, was cast from lead.

JANET WOODCOCK

The Seal of Approval

This 10-foot-tall, 5-ton WPI seal made from cast concrete is one of the few flourishes on Goddard Hall, an otherwise spare, modern building. The seal adorns the wall facing heavily traveled Salisbury Street, forming an elegant signpost for the thousands of cars that pass by each week. Completed in 1965, WPI's centennial year, Goddard is one of two academic buildings given to the Institute by the F.W. Olin Foundation. Its neighbor, Olin Hall of Physics, was built in 1959. Goddard, home of the Chemistry and Chemical Engineering departments, honors rocket pioneer Robert H. Goddard '08.



ROGER N. PERRY JR. '45

MICHAEL CARROLL

Timeless Beauty

The $500 needed to build the clock that now looks down from the tower of Boynton Hall was raised by the Institute's earliest students. Ironically, the clock became the bane of many a student in succeeding years as its gong (removed in 1890) summoned them to classes and tattled on those who tried to slip into their seats a few minutes late. Not surprisingly, students sought their revenge on more than one occasion by stealing the clock's gilded hands. Made, in part, from 1,500 pounds of cast iron, the clock was crafted by F.E. Howard & Co. in Boston. It was displayed in a store window in downtown Worcester for a few days before its installation on May 17, 1867.

JANET WOODCOCK

A Face in the Garden

The home of the late Aldus Higgins, chairman of Norton Co., Higgins House is an architectural gem, marked by a delightful mix of materials and styles. The house is filled with personal touches and flights of pure whimsy. The exterior, for example, is decorated with gargoyles of the animals that the Higgins family spotted on the property. This face peeks out from the ivy to greet visitors to the exquisite English Tudor gardens, a carefully planned network of flower beds, arbors, hedges and brick walks that adorn the Higgins House grounds.

Education On the Front Lines

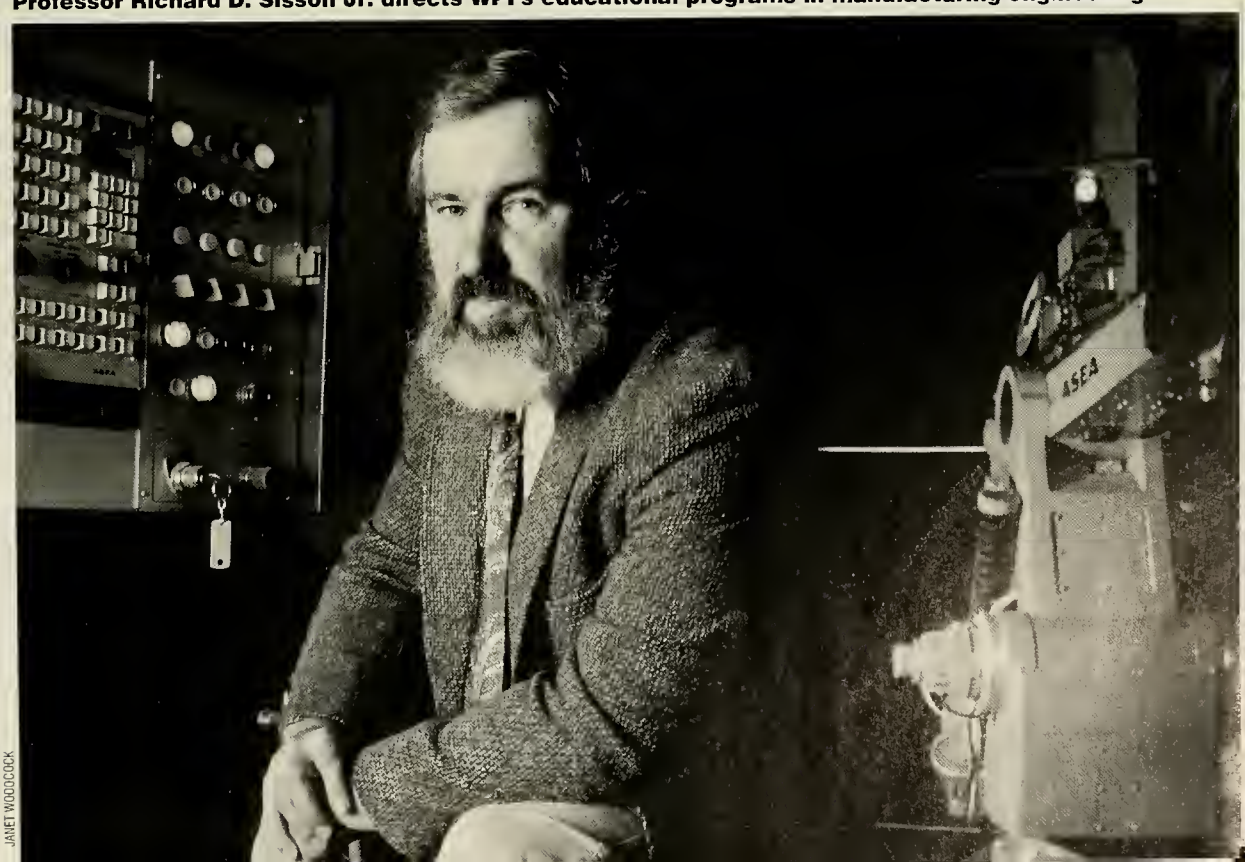
By Cathy H. Kalenian

Manufacturing engineering, WPI's newest accredited degree program, is preparing students to help meet the competitive challenges American industry faces today, and to create and manage the manufacturing companies of tomorrow.

For more than 125 years, WPI has been blending the theoretical and practical sides of engineering and applied science to produce graduates well-equipped to manage the manufacturing industries of the day, and to help create the manufacturing technologies of tomorrow. That tradition continues today, as the Institute expands and enhances its unique educational and research programs in manufacturing.

During WPI's formative years, students balanced their course work with hands-on practice in a model manufacturing plant housed in the Washburn Laborato-

Professor Richard D. Sisson Jr. directs WPI's educational programs in manufacturing engineering.



JANET WOODCOCK

ries, the oldest building in the nation used continuously for engineering education. By using state-of-the-art manufacturing tools to actually make useful and marketable products, WPI's early graduates gained insights into the manufacturing process that helped them found many successful industrial firms, including such leading Worcester companies as Wyman-Gordon Co. and Riley Stoker Corp.

In more recent years, manufacturing has been utterly transformed by computers, robots and advances in materials science. And while American companies competed primarily with one another 125 years ago, today they face a heated battle for survival in a constantly expanding global marketplace.

To educate a new generation of graduates to help American industry succeed on this highly competitive stage, WPI in 1986 launched a new degree program in manufacturing engineering. The Institute's newest accredited academic program, manufacturing engineering is preparing students to meet challenges WPI's founders could barely have dreamed of.

The roots of WPI's most recent manufacturing program can be traced back a decade to a large room on the lower level of the Washburn Shops, the site of the Institute's original shop program. In 1981 Walter L. Abel '39, then vice president of research and development at Emhart Corp. (now part of Black and Decker), and several fellow Emhart employees set up camp in that room to help the Institute establish a brand new laboratory in advanced manufacturing called the Manufacturing Engineering Applications Center (MEAC).

Through this joint venture, Abel, now president of Management of Technology in Avon, Conn., hoped to learn about the "breaking technology" his company and its many divisions (including the Tru-Temper Division and the Shoe Machinery Division) needed to remain competitive.

Emhart donated the lab's first robots and became its first charter member—followed quickly by General Motors Corp., General Electric Co., Norton Co., Digital Equipment Corp. and Heald Machine Corp. "That was a time when every company wanted robots," remembers current MEAC director Paul D. Cotnoir. "The drive was to eliminate classic bottlenecks on the manufacturing floor through the use of automation. The principal justification for the use of robots was labor reduction."

An Emhart division that made door-lock sets was the first to bring a real-world manufacturing problem to MEAC. Working with MEAC engineers, WPI students devised a robotic system that could undertake the labor-intensive process of assembling the various springs, small screws and other intricate parts. But while the system was not a success—the robot took 30 minutes to carry out a task that human workers could complete in a tenth of that time—the project demonstrated the feasibility of automating a complex manufacturing process.

Another early MEAC project was the Rivet Tool Test System (RTTS), which automated the testing of tools for Emhart's POP Fasteners Division. Using a robot and other automation equipment, RTTS replaced human operators in the repetitive task of inserting and setting individual rivets and observing the results over a long period of time.

For Norton Co., MEAC developed an automated work cell to unload and stack grinding wheels before they were fired. The system paid for itself in less than two years, based largely on materials savings. While MEAC has chalked up many other similar success stories over the years, its mission has evolved along with the notion of how automation fits into the manufacturing process.

Initially, Cotnoir notes, many companies hoped to see robots replace human workers in all manner of manufacturing operations, resulting in significant cost savings. Today, however, most manufacturing executives realize that robots are not the answer to every problem.

"Robots still work well in dangerous or repetitive operations, like welding," he says. "But the emphasis is no longer on developing 'islands of automation,' but on flexible automation—that is, systems that can respond quickly to design changes and variable product requirements. While labor savings are still important, increased production, efficiency and quality are even more critical. Now we spend little time

Smoothing Out the Rough Edges

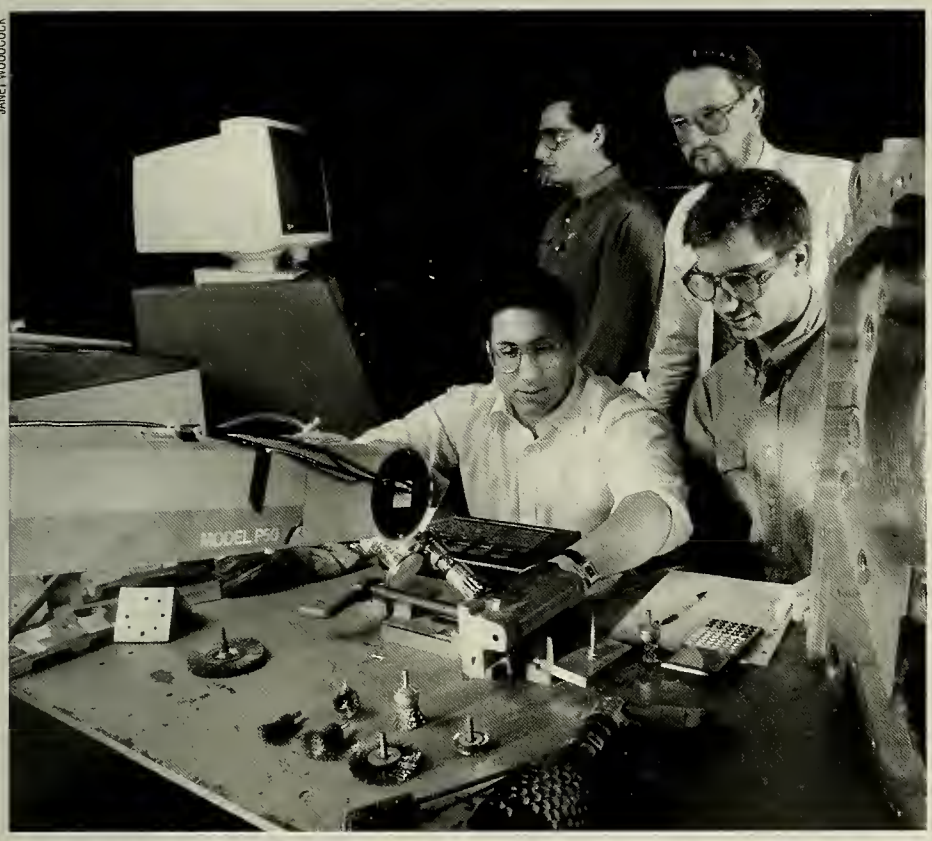
No matter how carefully they are machined, most metal parts must have their edges smoothed and shaped before they can be used. For manufacturers of aircraft engine parts, the processes of edge contouring and deburring are especially critical. In aircraft engines, sharp corners can create stress and adversely affect a part's service life. On the manufacturing floor, burrs and rough edges can make parts hard to handle and assemble. In service, burrs can break off and pass through the engine, causing catastrophic damage.

In 1991 WPI's Manufacturing Engineering Applications Center (MEAC) won a patent for a robotic system it developed in 1988 for General Electric Co. The system is capable of precisely contouring the edges of aircraft parts, while at the same time removing any burrs it encounters. "GE has been a longtime member of MEAC, so we're proud to have earned a patent for the company," says MEAC director Paul Cotnoir, who completed his master's thesis while working on the project.

Drawing on the work of other researchers, including a research group at MIT, the MEAC team tested as deburring tools nylon brushes impregnated with abrasives, abrasive grinding points and various types of rotary files. Because of their ability to reach the many recesses of the complicated metal parts, and because they can remove large amounts of metal quickly, rotary files made from tungsten carbide were ultimately selected.

When the files were attached to a robot arm selected for its high accuracy and stiffness, the result was a workstation that could successfully edge and deburr the titanium and superalloy parts, using the surfaces of the parts themselves as a guide. Spinning at 30,000 rpm, the files contoured the edges of the parts with an accuracy of two-thousandths of an inch. Just as important, the robot finished the task in less than an hour—about one-sixth the time needed to complete the operation manually—and virtually eliminated the need for rework and quality assurance checks.

Currently, WPI is engaged in a new deburring project for GE, which came about when Arthur Gerstenfeld, professor of management and director of WPI's Center for the Management of Advanced Automation Technology, was contacted by the GE Defense Systems Division in Pittsfield, Mass., which makes transmission housings for the Bradley Fighting Vehicle. The division wanted to develop a system to automate the deburring of the housings, a process now done manually with hand-held tools. The process is



JANET WOODCOCK

Clockwise from lower left, graduate student Fredric Gold, Reinaldo Niella '92, MEAC Director Paul Cotnoir and Rodrigo Gutierrez '92 use a brush attached to a robotic arm to deburr a sample of aluminum taken from a transmission housing for the Bradley Fighting Vehicle (a complete housing is seen at right).

time-consuming—it takes eight hours to deburr one housing—and inefficient—95 percent of the housings need some rework after the first deburring.

Gerstenfeld referred the request to John J. Bausch III, assistant professor of mechanical engineering, who completed his master's thesis at MIT in 1983 developing a similar deburring system. Bausch, in turn, received a grant from GE to create the new system.

Working with Bausch and Cotnoir, graduate student Fredric M. Gold has accepted the task of finding the best way to remove the burrs. Because the housings are made of aluminum, a much softer metal than the nickel-based superalloy used in the aircraft parts, the burrs need not be removed with the same degree of precision. Therefore, techniques may prove effective that were unsuccessful in the earlier project.

"Although brushes did not work for the aircraft engine parts, they may work fine for the aluminum transmission housings," Gold says. "Although this is not considered precision deburring, the method we choose must be thorough, because if a burr comes loose it can seize the entire engine."

While undergraduates Reinaldo F. Niella '92 and Rodrigo R. Gutierrez '92, who are completing work on their Major Qualifying Project, experiment with different types of brushes, Gold is investigating other methods of deburring, including electrochemical deburring, cascade deburring and tumbling. The latter two methods use hard particles that rub against the metal to wear down the burrs.

"We are experimenting with various types of media we might use with these methods," Gold says. "Anything hard can be used—even walnut shells. We also need to determine which method will be economically feasible for GE."

designing robot systems to do specific tasks; instead we automate whole manufacturing processes using a wide variety of state-of-the-art tools and techniques. We look at the big picture, providing solutions for the entire manufacturing floor."

In recent years MEAC has also turned its attention to how automation can help smaller industries that must fight the same battles for competitiveness as their larger cousins. With a grant from the now defunct Massachusetts Center for Applied Technology, MEAC helped introduce computer-aided design and manufacturing (CAD/CAM) to the state's smaller sheet metal firms to help them reduce the time it takes to create new sheet metal designs.

"The system is dead accurate," says John Colognesi, vice president of Southbridge Sheet Metal, one of the first companies to participate in the MEAC project. "We recently built a large, complicated frame made of tubular members and various angles. It would have taken a week of layout to develop it with traditional methods; with computer-aided design we developed it in a matter of a day." Colognesi says his company had long hoped to implement a CAD/CAM system, but lacked the time and resources.

More recently, Bay State Skills Corp., a quasi-state agency, hired MEAC to help the sheet metal industry export its products. "These efforts clearly illustrate the multidisciplinary nature of manufacturing engineering at work for area corporations," Cotnoir says.

In the years after MEAC's founding, the laboratory—which acquired a host of full-scale robots and automation equipment from its industrial partners—became the centerpiece of a manufacturing research and education program. In addition to teaching courses in robotics, manufacturing technology, materials and computer-aided design, faculty from the Mechanical Engineering Department and engineers from MEAC advised hundreds of undergraduate Major Qualifying Projects and nearly 20 master's theses in manufacturing.

In 1986 the Institute consolidated its expertise in manufacturing education into a new undergraduate degree program; a master's program was added a year later and the university's first Ph.D. candidate in manufacturing enrolled in 1989. In 1991 the programs received accreditation from the Accreditation Board for Engineering and Technology (ABET).

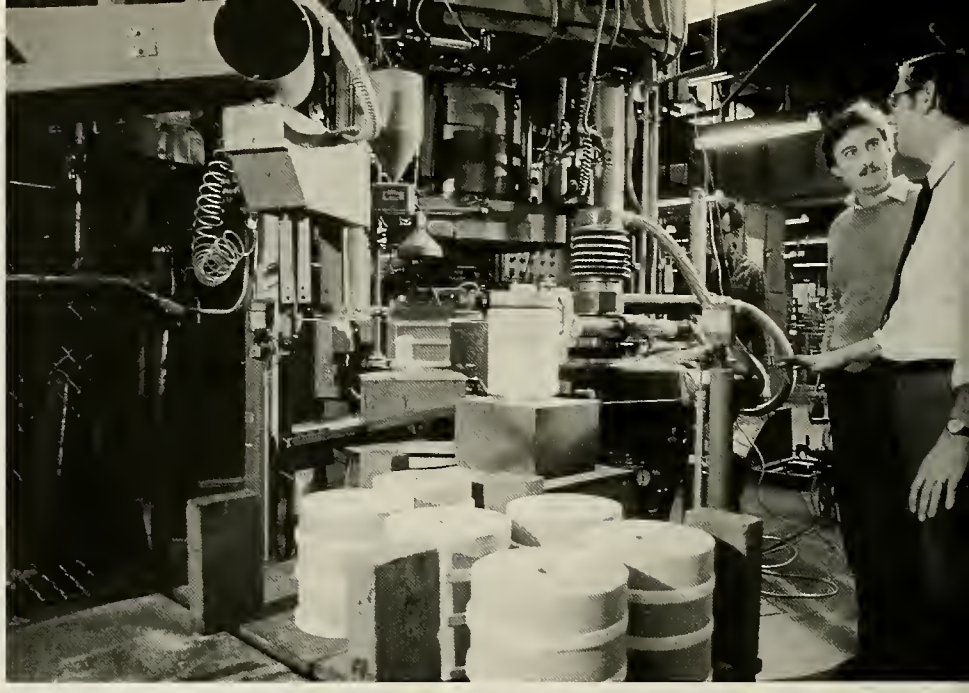
"There are only 10 ABET-accredited bachelor's degree programs in manufacturing engineering in the United States," notes Richard D. Sisson Jr., professor of mechanical engineering and director of manufacturing engineering. "WPI is one of the few places that offers B.S., M.S., and Ph.D. degrees. To date, we've had more than

60 graduates from the undergraduate program and five from the master's program."

Reflecting the multidisciplinary nature of modern manufacturing engineering, the curriculum is taught by faculty members from the Mechanical Engineering, Electrical Engineering, Management and Computer Science departments. The program includes four core areas of study: materials and processes; product engineering; computer control and manufacturing systems; and production systems engineering.

According to Sisson, the program emphasizes a systems approach to manufacturing, where students are taught to see the individual parts of the manufacturing process—from product design to manufacturing and testing—not as separate, unrelated processes, but as parts of a unified whole.

WPI's relatively young manufacturing engineering program has already begun to garner national attention. In 1990 the Society of Manufacturing Engineers recognized its first student honor society ever—the society founded by a group of WPI students led by Theresa A. Schmidt '92. The students petitioned the national organization when they realized that manufacturing engineering was the only major area of study at WPI that did not have its own honor society.



MICHAEL CARROLL

In this 1985 photo, former MEAC engineer Robert Bean, left, and Alan Cloutier of Norton Co.'s Vitrified Grinding Wheel Division look over a MEAC-designed system that unloads and stacks grinding wheels, seen at center, before they are fired.

Materials and processes, the first core area of study, explores the properties of modern manufacturing materials and looks at how they react to such processes as casting, forging, injection molding and grinding. Understanding the fundamental mechanisms by which materials are shaped and new surfaces are created is critical in modern manufacturing, notes Christopher A. Brown, assistant professor of mechanical engineering, who heads up this area.

"Many students arrive thinking that manufacturing is all robots and computer controls," Brown says. "But if we're only intelligently controlling the same old processes, we haven't necessarily reached our potential for effective manufacturing. That's why my teaching and research focus on where the tool meets the workpiece."

Brown, whose research specialty is conventional and electric-discharge machining, has been a pioneer in the study of machined surfaces. To better understand the characteristics of these surfaces he uses fractal geometry, a new form of analysis he first employed while doing research on machined surfaces at the Swiss Federal Institute of Technology in Lausanne.

"Fractal geometry allows us to characterize the essence of complex shapes, such that their character is represented over a wide range of scales," he says. "Over the last few years, we've been able to use scanning electron microscopes and scanning tunneling microscopes to generate hundreds of thousands of bits of data about the topography of a machined surface at the atomic scale. Theoretically, with such data we can now approach product and process design issues over a range of scales that extends right down to the atomic level."

Fractal analysis can prove especially useful in situations where a designer must create a part that has to perform different, seemingly contradictory functions at different geometric scales, Brown says. "For example," he notes, "a substrate for a coated cutting tool needs to be smooth at larger scales, but rough on a fine scale to effec-

JANET WOODCOCK

From left, graduate students Robert DeLang and Kris Timmermans and Professor Christopher Brown test the effects of electric-discharge machining on a ceramic sample. DeLang and Timmermans are students at Catholic University in Leuven, Belgium.

tively anchor the coating. Fractal analysis helps us see how to decouple large- and fine-scale functions and manufacturing processes and handle them separately."

At the other end of the manufacturing spectrum is production systems engineering—the use of effective management and organizational techniques to produce a high-quality product manufactured by motivated employees. To accomplish this goal, production engineers use production planning and control, quality planning and control, risk analysis, and simulation, among other techniques.

"This fourth core area of study rounds out a manufacturing engineering degree program that prepares students to be equally skilled in areas that range from industrial robotics to advanced materials and processes," says Enio E. Velazco, assistant professor of management. "But in addition to being technologically ready, graduates of this program will be prepared to analyze and improve operational systems from a human standpoint."

Notes Sharon A. Johnson, assistant professor of management, "The kinds of questions we pose to our students include: What and how much do I produce this month to limit inventory, but still satisfy my customers? Can I economically justify the cost of a new product design? Can I improve a process by reducing setup time, while still maintaining quality? How does automation affect my company's organization and impact workers?

"We're asking the students to look at the big picture. Automation and new technology must be reviewed on the basis of how they relate to all functional areas within a company. The human factor is very important."

To learn firsthand how to put these management tools to work in real-life situations, students who specialize in production system design often complete their Major Qualifying Projects in the field solving problems for sponsoring companies. For example, Rosana A. Espino '93, Erik H. Krauss '92 and Andrea K. Toland '92 are working with Dover Instrument Corp. in Westboro, Mass., which customizes precision air-bearing positioning systems, to develop a computerized scheduling tool that will analyze capacity and resource utilization in the company's manufacturing department.

The scheduling model, which will be used to plan projects on a monthly basis, will provide feedback to the sales department, helping the sales force quote shipping dates to customers. Because Dover is a small company, the students are attempting to fashion a system that will not require the firm to purchase new equipment or add personnel.

Jodi A. Pisinski '93, Jennifer L. Wood '92 and Tara Lynn Zaharoff '92 are working with Norton Co. to develop a recycling program for the abrasives the company uses to make grinding wheels. The students will address the technical, environmental and economic feasibility of a recycling program, and attempt to design a program that will not adversely affect the manufacturing process.

To prepare students adequately to manage modern manufacturing enterprises, the WPI faculty strive to expose them—in the classroom and through projects—to the most current techniques in production management. More often than not, these are techniques that were pioneered by Japanese firms. One example is the Taguchi Method, a technique based on statistically designed experiments that allow engineers to analyze operational systems, identify the effect of various factors on particular measures of performance, and prioritize various methods for improving the manufacturing operation.

"Our students are learning to be critical of the status quo, and to always look for possible areas of improvement," says Velazco, whose teaching focuses on statistical quality control. In the classroom projects that Velazco assigns, students are asked to analyze data that have already been used by engineers at real companies to solve manufacturing problems.

"In some cases, the students have come up with different solutions than the ones the engineers found," Velazco says. "When time allows, we meet with the engineers to determine if improvements can be made based on the students' findings.

"My effort to present the latest Japanese manufacturing techniques to students is reflected in the number of MQPs and master's theses that students have undertaken focusing on the Taguchi Method," adds Velazco, who, with help from a grant from General Electric Co., is currently developing a new undergraduate course in Total Quality Management, another leading-edge management technique.

Students pursuing undergraduate and graduate degrees in manufacturing engineering at WPI can complete their MQPs, theses and dissertations in industry-sponsored centers and laboratories in robotics, flexible automation, process control, advanced materials processing, and computer-aided design and manufacturing, among other disciplines. Students specializing in the human side of manufacturing can

JANET WOODCOCK

Andrea Toland '92, center, discusses the computerized scheduling tool she is helping develop for Dover Instrument Corp. with management professors Sharon Johnson, left, and Enio Velazco.

This Robot's Way Above Par

Computer-integrated systems and intelligent process controls are as important to manufacturing operations as the automatic hardware itself," notes John J. Bausch III, assistant professor of mechanical engineering. "For a great many traditional processes, better control software is the only mechanism available to improve performance.

"One of the long-range objectives of computer-integrated manufacturing is to close the gap between design and manufacture," he adds. "By combining computer-aided design methods to model a part with computer-aided manufacturing methods to produce it, we can completely automate the manufacturing process."

Working with David C. Zenger and David J. Olinger, also assistant professors of mechanical engineering, Bausch is currently advising three groups of undergraduates who are studying intelligent process control by creating a robot that might seem more useful on the golf course than on the factory floor. Called the Integrated Putting Robot, the machine can size up the bumps and contours of a green and figure out the best way to swing a putter to drop the ball in the hole.

"Though the end result may not be closely tied to the typical manufacturing operation," Bausch says, "the ability to program the robot system to analyze the green surface and adopt the trajectory of its stroke in real time is extremely valuable. This is actually a very realistic manufacturing problem."

JANET WOODCOCK

From left, Sean Doherty '92, John Berube '92, Professors John Bausch and David Zenger, Michael Vecchione '91, Professor David Olinger, and James McCleery '92 form the gallery as the Integrated Putting Robot attempts to sink a four-footer on this carpet-covered "green."

The robot had its origins in an idea Zenger had for a fun way to cap his course in robotics. Each student in the class develops a program for the robot, which holds a standard putter in its arm, and practices putting on a flat green.

complete projects through the Center for the Management of Advanced Automation Technology (MAAT), which, under the direction of Arthur Gerstenfeld, professor of management, helps industrial sponsors overcome the obstacles that often stand in the way of implementing and benefiting from advanced automation.

The newest center, the Center for Intelligent Processing of Materials (CIPM), is one of two multidisciplinary research centers recently created at WPI as part of the Institute's *Strategic Plan for the 1990s* (the other is the Applied Bio-Engineering Center). Directed by Richard Sisson, the center is the umbrella organization for a number of laboratories.

According to Sisson, the goal of the new center is to create intelligent systems for the processing of materials by integrating three fundamental manufacturing subsystems: an interactive database of mathematical and heuristic models of materials processes; advanced sensors and data-acquisition systems that measure key attributes of the materials; and a supervisory control system that utilizes the models and the sensors to intelligently control the processes.

"More broadly," he says, "we will seek to develop the kinds of integrated, interactive and intelligent processing systems that American industry will need to create products that are competitive—both here and abroad. In the process, we're also providing a valuable learning experience for WPI students."

One of the first of the new laboratories to fall under the CIPM umbrella is a facility for the study of electric-discharge machining (EDM). "Through the center we are seeking to advance our understanding of the spark-erosion process," notes Christopher Brown, the lab's founder. "The goal is to extend the capabilities of EDM beyond its current applications—primarily machining hard metals for making tools and dies—to new areas, like the production of ceramic components."

Other CIPM centers include the Center for Hydrogen Embrittlement of Electroplated Fasteners, which addresses the scientific and industrial problems associated with the fasteners (lost time, accidents and product liability due to embrittled fasteners cost corporations millions of dollars each year), and the Center for Carburization Heat-Treatment Studies, which helps industries streamline and optimize the traditional carburization process, a method of impregnating carbon into metals using heat.

Recently, six WPI researchers, under the auspices of CIPM, submitted a proposal to

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From left, Christopher Maxwell '92, Christopher Kelley '92 and Jeffrey Poggi '92 work on software that will tell the putting robot how to translate a "putting plan" formulated by a computer model into the proper swing of the putter.

They then compete against one another, providing manual feedback to the robot until it can sink a putt on the same green, which now has a few added contours.

"At Professor Olinger's suggestion," Bausch says, "we created this Major Qualifying Project to automate the process of adjusting to the changing green surface. Now the robot will probe the putting surface, analyze the information, and adjust the speed and the arc of its swing appropriately. Our hope is that the robot will do better on its own than it does under the students' control during the competition."

To complete the task, one group of students (Christopher D. Kelley '92, Christopher A. Maxwell '92 and Gregory R. Tucker '92) is developing a computer model to predict the path of the ball and choose the initial ball velocity and direction. Another team (Jeffrey P. Poggi '92, Johan Van Achterberg '91 and Michael F. Vecchione '91) is developing an application program to generate the surface of the green on a computer screen and simulate the motion of the robot and the ball.

The third group (John A. Berube '92, Sean T. Doherty '92 and James A. McCleery '92) is developing the software that will translate the output of the models into the proper movement of the robot arm. Each "putting plan" will be fed to the robot and tested; if the robot fails to sink the ball, the students will reanalyze their models and assumptions.

Bausch says the most important aspect of the project is the fact that it brings together different specialities within mechanical engineering to develop a successful automated process. "The analysis group tends to consist of students interested in aerospace and numerical methods," he says. "The computer-integration group consists of ME majors with a broad interest in advanced computer systems. And the computer-aided manufacturing group is more hardware-design oriented."

"Whether at WPI or in the real world of industry, professionals with varying specialities must learn to work together," says Zenger. "That's the real goal of the Integrated Putting Robot project. While each student in this project has his own expertise, the end process will not be successful unless there is a group effort and good communication."

the U.S. Army for funding for a major project on the intelligent processing of powder metals. Notes David C. Zenger, assistant professor of mechanical engineering, the project will seek to integrate the various aspects of powder-metal processing—from the analysis of the metal to the design of the manufacturing systems—all of which are now studied in isolation.

"Our goal is to develop the framework for an interactive, integrated and intelligent system so that design and process flow together concurrently," he says. "Since 70 to 85 percent of product cost is determined at the earliest stages of product design, there is an incentive for early optimization of product design and accurate prediction of the manufacturing and processing requirements."

Since its founding days, WPI has measured its success in many ways, but the most important bottom line has always been the success of its graduates. For a young program, manufacturing engineering has already achieved its share of success, notes Sisson.

"Our graduates are doing quite well in industry," he says. "Many are being hired by large corporations for their management and manufacturing engineering training programs. For example, General Electric's Manufacturing Management Program hires many of WPI's manufacturing engineering and mechanical engineering graduates. In addition, many graduates are working with small companies, providing them with state-of-the-art engineering expertise that will help them stay competitive."

For these students, the education they received at WPI—in particular the real-world projects—have provided a significant edge in the work place, Sisson says. "Our approach to manufacturing education lets students apply their newfound knowledge and problem-solving skills to real-life situations. They have to solve problems within the same cost and time constraints they'll face once they get out there on the real shop floor. There is no substitute for that kind of experience.

"Our students are not working in a vacuum," he adds. "They are out there in the field, developing a human touch. Graduates of our manufacturing engineering program will be tomorrow's top manufacturing executives, leading companies into the 21st century using skills developed at WPI and tested in the field."

Kalenian, a free-lance writer living in Princeton, Mass., once ran a manufacturing business with her husband, Paul A. Kalenian '76.

Steady as She Goes

By Michael W. Dorsey

When he can, Robert H. Beckett '57, chairman and CEO of Robec Distributors in Horsham, Pa., likes to leave behind the demands of his busy life and go sailing on the Chesapeake Bay. Like the countless generations of watermen who've navigated this vast inland waterway before him, Beckett knows that negotiating the Chesapeake requires a steady hand on the tiller and a clear vision of where you're going and how you're going to get there.

Beckett has taken a similar approach to his own career. Though his desire to create and manage his own company surfaced early in life, he waited more than two decades until the time and circumstances were right to make the leap. "I started talking about starting my own business when I was a senior at WPI," Beckett says. "But I didn't know what to do or when to do it. Later, I was concerned about my kids—I didn't want to jeopardize their educations. But I always knew that someday I would start my own company."

PHOTOS BY MICHAEL DORSEY

Robert Beckett '57 in the warehouse of the 105,000-square-foot headquarters of Robec Distributors in Horsham, Pa.

That someday arrived in 1978. With his employer, Decision Data Inc., facing a serious financial crisis, Beckett was forced to take a critical look at his career options. He decided the time had come to go his own way. At that time, desktop computers, which were still in their infancy, were already making inroads into business and industry, and Beckett could see that virtually unlimited opportunities existed for entrepreneurs who could find their own niche in this rapidly expanding market.

With G. Wesley McKinney, a Decision Data sales executive, Beckett founded Robec Inc. The company's first venture was a new software product aimed at surveyors and real estate developers. Given critical information about a parcel of land, the product could help carry out the financial and technical analyses involved in turning the land into a finished development. The software could even subdivide the land into lots, add streets and utilities, and draw the results on a plotter.

"We took the package to the state surveying show at the University of Pennsylvania and immediately got a request to demonstrate it to the executives of a large surveying instrument manufacturer," Beckett says. As a result, Robec won a contract for nearly $2 million worth of hardware and software, including 120 Z/80 desktop computers and associated printers and plotters.

Around that time, Okidata, a manufacturer of computer printers, released a new printer for personal computers. Impressed by Robec's experience with printers and its sales success, Okidata provided the opportunity for the company to act as a distributor. Robec agreed, and in the process firmly established itself as an up-and-coming wholesale distributor of microcomputers and peripherals. It's been more than a decade since that day, and Beckett has never looked back.

More than anything, it was football that first brought Robert Beckett to WPI. The son of a machine shop inspector who emigrated to the United States from Belfast as a young man, Beckett was born in Trenton, N.J., in 1933. As a student at Hamilton High School in Trenton, Beckett excelled at mathematics and physics and played on the football team. After graduating in 1951, he spent a year at The Pennington School, a New Jersey preparatory school.

Beckett's academic credentials earned him admission to several colleges, including Lafayette, Delaware and Rutgers, but financial constraints led him to put off college for a year. "I had actually enrolled at Lafayette and attended freshman orientation," he says, "but I decided not to start until I could gather additional financial support."

Instead, to earn money for college he worked in the service department of a local Ford dealership as a mechanic and a service salesman. In the evenings he held down a second job on the night shift at a gas station. That fall Beckett's prep school football coach told him that Charles McNulty, football coach at WPI, would be visiting the area to look for good students interested in a technical education. Beckett agreed to meet him.

"McNulty and I talked in December and he invited me to visit WPI the following spring," Beckett says. "I had such a desire to go to college someplace, and I was so pleased to find someone who seemed willing to help. Not having the financial wherewithal to go to college, and feeling the frustration that goes along with that—that was a low point in my life. I've always appreciated how WPI made it possible for me to get an education."

With the aid of a matriculation scholarship, Beckett enrolled in the fall of 1953. "I still had to work to earn money for expenses, but I enjoyed my years at WPI. I got a lot out of my education."

While at the Institute, Beckett was a member of Sigma Phi Epsilon fraternity and joined the Athletic Council, the Varsity Club, ROTC and the American Society of Mechanical Engineers. He was on the staffs of *Tech News* and *Peddler*, and was elected to the Tech Senate each of his WPI years, serving as president his senior year. He also won election to Skull, the senior honor society, and Phi Delta Epsilon, the journalism honor society.

In addition to his activities, he was active in sports, competing on the swimming and tennis teams as a freshman and sophomore. As a guard on the football team, he lettered as a junior and a senior and played on the undefeated and untied team of 1954. "I wasn't a star," Beckett says, "but I was a steady player. I'm still that way. I'm one of those people who likes steadiness and stability. I think that's one of the things that has made Robec successful."

Robec's regional distribution centers keep busy shipping microcomputer systems out to customers around the country.

Early in his career, Beckett learned the rewards that stability can bring. After completing six months of military service, he joined Leeds & Northrup in North Wales, Pa., a maker of electronic recorders, controllers and test instruments. On-campus interviews had earned him offers from eight other companies, including Alcoa, Curtis-Wright, Goodyear and IBM, but none of these firms could promise Beckett a position that would let him make full use of his engineering education.

"I didn't want a position that could be filled by a nontechnical college graduate," he says. "I thought to myself, 'If they don't put any value on a technical education, why did I bother to get one?'"

A friend had suggested he check into Leeds & Northrup, and while he was home for Christmas vacation during his senior year he visited the plant. "I was so impressed with the kind of job they offered me—it just hit me right," he says. "It was exactly what I wanted."

Beckett started out in field sales in Milwaukee. "The Midwest is warm and friendly, but difficult to penetrate," he says. "But I outlasted the competition. I was there for five years, and in that time the Honeywell representative changed twice. All of a sudden, I was the veteran; mine was the face the customers had seen more often, so I started to get more business."

From Milwaukee, Beckett was transferred to Pittsburgh, where he played a critical role in developing instrumentation and central control systems for steel plants and plants that processed taconite, a low-grade iron ore.

"That was a time when industry was just beginning to centralize operations," he says, "using miniaturized instruments to gather raw data from throughout the processing operation and pulling it into a central location. Centralization was an essential step before you could even consider putting in a computer. Once you had all the data in place, you could figure out how to handle it through mathematical models of the process."

While at Leeds & Northrup, Beckett and a fellow employee, Ken Bullinant, were approached by Don Stein, the president of a small Glassboro, N.J., instrumentation company called K-Tron Inc. Stein was interested in developing some new measurement devices for industrial processes, and Beckett and Bullinant spent several weekends at K-Tron completing the design for one of Beckett's ideas, a gravimetric feeder. All three would ultimately share a patent for the design.

"A gravimetric feeder measures the weight of dry granular material as it passes along a conveyor belt, controlling the volume of the stream as a function of its

weight," Beckett says. "When you're blending multiple streams—for example, mixing other ingredients in with dry cereals or controlling the ratio of raw ingredients feeding into a plastic extruder—a gravimetric feeder enables you to get the same formulation all the time."

Eventually Beckett and Bullinant left Leeds & Northrup to join K-Tron, where they converted their original pneumatic feeder to an electronic device. It was the first digital feeder on the market and remains the standard in the field today, Beckett says.

After five years at K-Tron, Beckett left to join Decision Data Inc. in Horsham, Pa., a manufacturer of equipment for IBM System 3 business computers. As manager of OEM (original equipment manufacturer) marketing, Becket sold Decision Data's products—including card readers, punches, reader-punches, and printers—to other computer manufacturers. He also spearheaded the launch of a new 120-character-per-second dot-matrix printer.

In 1976 IBM announced its intention to entirely redesign its System-3 computers, making many of Decision Data's products obsolete and placing the company's future in doubt. For Beckett, it was a critical turning point—one for which he'd been waiting for 22 years. By 1978 he would be president and CEO of his own company.

The qualities Robert Beckett uses to describe himself—steadiness and stability—could apply as well to the company he founded 14 years ago in Montgomeryville, Pa., a suburb of Philadelphia. As a value-added distributor of microcomputers, peripherals, software and supplies, Robec Distributors sells its products to about 22,000 customers, who include value-added resellers (VARs), retailers and other computer businesses that, in turn, sell those systems to end-users.

Since its birth, Robec has grown at a quick but steady pace. Starting in 1978 with a work force of just the two founding partners, Robec grew to employ 20 people and earn annual sales of nearly $4 million by 1982. Four years later its sales had jumped to more than $68 million—an increase of over 1,500 percent—and its work force had risen to 128.

The company passed the $100 million mark in sales during its 10th year of operations in 1988, and today Robec posts annual sales of more than $200 million with a work force of 410 nationwide, including 180 in Horsham, Pa., where the corporate headquarters were moved in 1987. This rapid expansion earned Robec the No. 10 spot on *Inc.* magazine's list of the 500 fastest-growing privately held U.S. companies in 1984. The company appeared on the list again in 1985, 1986 and 1987. Robec's success also earned Beckett the title of Delaware Valley Entrepreneur of the Year in 1988 from the Arthur Young Co. and *Venture* magazine.

WPI has also honored Beckett, who has served the college since 1986 as a trustee, and who, as chairman of the board's Development Committee, helped manage the highly successful *Campaign for Excellence.* (Beckett's own gifts to the Institute helped build the new George F. Fuller Laboratories.) In 1987 WPI presented Beckett with its Robert H. Goddard '08 Alumni Award for Professional Achievement.

Robec's growth has been partly fueled by acquisitions. In 1985 the company purchased North Carolina-based InterAct Distributing, which added a network of offices and warehouses in the South to Robec's own regional sales offices in Boston, Mass., Reston, Va., and Youngstown, Ohio. Other acquisitions, including the purchases of regional computer distributors in Texas and California, have enabled Robec to become a truly national company comprising 20 branch offices from Seattle to Orlando, including regional operating and supply centers in Horsham, Kansas City and Phoenix.

"Territorially, that's all I want to do right now," Beckett says, "at least until I get all of our offices as strong as our East Coast offices. We might look at other locations in the future—potentially in Canada and Mexico, if trade barriers come down."

Robec's steady growth is particularly striking when projected against the backdrop of the ups and downs of the computer industry over the past decade and a half. As

MicroStack and the WPI

Since they were introduced less than a decade ago, personal computer networks have helped businesses boost their productivity by linking individual personal computers together, enabling users to more easily share information and data. But even with the most powerful commercially available networks, companies can run into problems when they try to expand their networks to accommodate new users or new technology.

A unique approach to networking developed by Robec Distributors, with help from researchers at WPI, promises a simple yet easily expandable personal computer network. Called MicroStack, the system combines the power and resources of two or more off-the-shelf personal computers to create a multiprocessing computer. The system enables users to share memory, disk drives, printers and other peripherals connected to the stack, in much the same way that users of much more expensive mainframe or minicomputer systems can.

"Our concept was that all the processing power of a networked system should be transparent to the user," says Robec Chairman and CEO Robert H. Beckett '57. "All he wants to see is that he has the resources he needs to get the job done. Where those resources are located shouldn't concern him."

NEIL NORUM

James Duckworth, seated, holds the Bus Interface Card he developed for MicroStack, Robec's revolutionary networking solution. David Cyganski stands beside a MicroStack setup running a test on TCPserver, the addition he wrote for the MicroStack operating system.

While MicroStack makes use of hardware and software sold by other vendors, two key elements are available only from Robec. The

Connection

first is the operating system, called Shared Resource Architecture, which enables several PCs to work as one computer. The other is the Bus Interface Card (BIC), the hardware that links the computers together and permits the rapid and orderly exchange of data between them.

The BIC, a card that plugs into each of the PCs in the stack, was developed by R. James Duckworth, associate professor of electrical engineering, working under contract to Robec. "There were some special requirements for this card," Duckworth says. "It had to interface with the rest of their software, it had to support very high-speed but reliable communications between a number of PCs, and it had to be low cost."

Working with graduate student Kenneth Viall, Duckworth produced a board capable of transferring data at the rate of 2 million bytes per second. Key elements of the design included an advanced microprocessor, a SCSI controller (normally used to transfer data between a computer and a disk drive), and a special memory design that maximizes the card's throughput.

"We wanted the host PC to be able to write new information to the BIC at the same time that the BIC is sending previously received information out into the stack," Duckworth says.

Duckworth not only designed the BIC and produced a prototype for Robec's approval, but supervised the manufacture of the cards by a local company. More recently, he and another graduate student, Samer Nubani, produced a new version of the card with a faster microprocessor and controller that increased its communications speed to 5 million bytes per second. By integrating several functional elements of the old card into a small number of programmable logic devices, they also made the card easier and less expensive to manufacture.

Nubani says his work on the BIC was equivalent to a "year's industrial experience," and credits the project with helping him land a job as an engineer with Teleglobe Inc., an electronics company in Canada.

In addition to supporting the development of the BIC, Robec provided computers and test equipment for WPI's Computer Architecture Laboratory, where much of the development work for the BIC took place. More recently, David Cyganski, professor of electrical engineering, and graduate student Michael J. Haley have used the resources of this lab to add a new feature to the Shared Resource Architecture.

Called TCPserver, the new feature will allow MicroStack to communicate with workstations, mainframe computers and networks that use the Unix operating system as easily as it now does with PCs operating under the DOS operating system. Unix machines generally communicate with the TCP/IP protocol, which is incompatible with protocols generally used in computer networks that link DOS-based computers.

"This new addition will let MicroStack enter the all-important world of Unix computing, making its capabilities available to a much broader range of computer users," Cyganski notes.

Using the enhanced Shared Resource Architecture and the BIC, MicroStack can link up to 63 individual PCs and dozens of peripheral devices, and can interface with terminals and PCs hooked into virtually any type of computer network.

"We think it's a really exciting development," Beckett says. "One person who read about MicroStack said, 'You don't have an evolutionary product here—you've got a revolutionary product. It changes the whole way of thinking about networks.'"

Robec completely assembles and tests every computer system it ships from its warehouses.

Robec's own newsletter noted in 1986, the market for microcomputers experienced a "blip" in 1982 when the IBM Personal Computer was introduced, "convincing millions of end-users that it was safe to go micro." But after the blip came the "dip," when the flurry of demand for computer products that followed the introduction of the IBM PC began to taper off.

Later, as the business and home computer markets became more saturated, the computer market softened and many computer makers went out of business or suffered hard times. More recently, the recession has further cut into the demand for computers and related products.

What has enabled Robec to sail steadily on through these sometimes stormy seas? Beckett attributes much of the company's success to its unique approach to computer distribution. Most computer distributors, he says, have concentrated on selling high volumes of individual components, such as personal computers, printers and disk drives. Robec has, from the beginning, placed its emphasis on selling whole systems, including everything—computers, peripherals, software, and networking equipment—that end-users need to use computers effectively in their businesses.

"In the beginning, the big distribution companies were all commodities oriented," Beckett says. "The market was growing so fast, all you had to do was pick up the phone and you could sell something to

somebody, as long as you kept your prices low. Robec is dispersed over multiple offices and our costs are too high to compete on that level, so we've always worked hard to keep the commodity sales—what I call the pull sales—from dominating the higher-margin system sales—the push sales. We've kept a balance between push and pull—between the value-added and commodity sales. That's really our strategy."

Because Robec's emphasis is on systems, rather than components, the company can also provide its customers with a high level of support services. For example, it completely assembles and tests every system it sells before it is shipped—often with all the software installed—to assure that no problems will develop once the equipment leaves the warehouse.

"I don't know of many other distributors who are doing that," Beckett says. "We actually format the drives, load the operating system, and log on all the peripherals. When we ship it to the customer, all he has to do is set it up and turn it on." Robec is also one of the few distributors that maintains an in-house maintenance department.

Unlike most computer distributors, Robec also invests heavily in education. It offers seminars and workshops on microcomputers and software, frequently mounts multicity tours to introduce its customers to new technology, and prepares its own correspondence courses. "When you distribute technology," Beckett says, "You have to spend a lot of time educating people and introducing them to the things you think will help their businesses. That kind of leadership is what's helped us be successful."

As the computer market has matured and competition among distributors has increased, Robec has shifted more and more of its business into these value-added services, which earn much higher profit margins than volume sales of computers or commodities. The value-added segment of his operations grew from 12 percent of overall sales in 1987 to 36 percent in 1990. "We're not the largest distributor in this business," Beckett says, "but our model says we don't have to be because we're the most profitable distributor. And that's what will sustain our business.

"As long as we maintain a feeling for the marketplace and the customers are willing to pay for the services we offer, we'll succeed," Beckett says. "A lot of people say they are value-added distributors, but the only ones who really are, are the ones whose customers are willing to pay for that value."

There is no better way to sell people on an idea than to put that idea to work yourself," Beckett says. At Robec, that's more than a philosophy—it's a way of life. In a business where suppliers and dealers must convince customers that, given the right technology and resources, they can make their business more effective and efficient, Robec leads by example.

The company recently purchased and installed its own voice-mail system. It is now in the process of automating its warehouse without outside help. Even the company's modern, 105,000-square-foot corporate headquarters and warehouse in Horsham is a monument to this do-it-yourself spirit: Robec employees planned the renovations of the original 45,000-square-foot-structure and supervised all of the work. The company also acted as general contractor for the construction of a 10,000-square-foot office annex and a 50,000-square-foot warehouse expansion.

Touring the building, a visitor quickly sees that Robec also practices what it preaches when it comes to the technology it sells. Virtually every administrative task carried out in corporate headquarters makes use of the microcomputers and software Robec distributes, and all of the company's computers—as well as all of its regional offices—are linked together with the company's networking systems.

Using the products it sells is the best way to thoroughly understand how they work, Beckett says, and to anticipate the problems end-users may encounter in employing them in their own applications. To this end, Robec puts its own business systems to the test. Consider the tricks it asks its networks to perform every day:

Each evening, after normal business hours, computers in Horsham call each branch office and collect data on the day's transactions. Data from Robec's entire national distribution operation is consolidated and analyzed. The updated results are then fed back to the regional offices. On top of this, local networks at headquarters and at each branch office constantly keep track of new orders, automatically updating records in multiple offices, and printing out invoices and shipping documents.

The company is currently implementing document imaging, a technology that replaces traditional paper files with electronic images that can be easily retrieved and viewed on a computer screen. "For example, with the imaging system, all shipping documents arriving in our receiving department will be scanned into the computer," Beckett says. "They will be electronically attached to the purchase order, which will already be in the system. The payables department can then pull these documents up on the screen, check them over, verify the signatures, and pay the vendors. We may even scan in the checks and attach them to the other documents.

"Eventually, we plan to do away entirely with historical files. After we thoroughly understand the system, we can educate our VARs about how to use it and sell it. I believe there will be a huge market for imaging systems in the next five years, as the prices for the technology continue to come down."

Robec's emphasis on selling complete computer systems enables it to offer customers a broad range of services, such as this maintenance and repair facility.

Robec Distributors has become a family affair for Beckett. His wife, Pat, above, has long served as his administrative assistant. His daughter and two sons also work with him at corporate headquarters.

Imaging is an example of how Robec is expanding into new high-end technology, instead of into new territory, Beckett notes. "In addition to imaging, we're getting into multimedia applications, heavier networks and network management, and workstations," he says. "Because of our commitment to service and support, I think we're in a better position to market these products than many other distributors."

In addition to products made by other companies (Robec is an authorized distributor for about 50 computer and component manufacturers, including Motorola, Okidata, Sony, Unisys, Texas Instruments and Wyse), the company has also from the beginning developed its own business software.

Its first package, the Robec Simplified Business System, originally ran on one of the first Z/80 desktop computers. The software provides the kind of real-time business support (sales-order entry, inventory control, accounts receivable and payable, purchasing, and so on) that is usually attainable only on larger computers, and makes it available on a network of personal computers. Robec has also developed its own communications software, Solo-Com, and a unique, low-cost approach to networking called MicroStack (see related story).

Most of these packages are the products of Robec's own research and development department, which is headed by Alexander C. Kramer Jr., vice president for advanced systems technology. Kramer, who earlier in his career developed one of the first operating systems for real-time process controls, is one of four Robec employees who worked with Beckett at Leeds & Northrup. In addition to McKinney and Kramer, they are John P. Puckett, senior vice president and general manager, and Charles Shaffer, director of operations for Base Two, a Robec subsidiary.

Beckett says the Leeds & Northrup connection is significant, because that company's emphasis on system sales and applications helped shape Robec's own philosophy. But even more, it is a reflection of the value Beckett places on loyalty. He points with pride to the unusually low turnover among Robec's employees. "We have some young people in sales who have been with us for seven years," he says. "Seven years in the micro industry is an enormous amount of time—and they're not the older salesmen, they're the younger ones."

Beckett says he is also proud that his family has chosen to join him in the business. His wife, Pat, is his administrative assistant. His oldest son, Robert Jr., is secretary and vice president for marketing operations. His daughter, Susan K. Childers, is manager of advertising and publications. Son Thomas recently joined the firm after receiving his degree in marketing from Pennsylvania State University.

"That's the way this company is," Beckett says. "We don't constantly try to change direction, like some of our competitors. We stay with our people and our strategy, because that's what works the best."

Climbing Between the Peaks

A successful fund-raising campaign should achieve three significant outcomes: raising dollars and pledges for its objectives; accelerating the process of giving; and moving the institution to a higher "results plateau" from which to conduct future fund raising.

This article will address the third objective—fund raising between campaigns, or "climbing between the peaks." Note that I didn't say *descending*. Experienced mountaineers know that while going downhill awhile before making another ascent is refreshing, it makes reaching the next summit seem all the harder. Right now WPI is in such an interregnum—having reached a hard-won peak of $63.7 million, we are looking ahead to the next summit.

So what are our plans for the next few years? For what do we need significant funding? I'll start with some simple premises. First, WPI is a distinctive, high-quality institution that serves students at the higher end of the talent range. Second, to continue to offer its considerable diversity of programs, the Institute has been reaching out to serve students who reside well outside the founders' "drawing boundaries" of Central New England.

Most of our current benefactors and future prospects will likely embrace these premises, for they want WPI to remain among the best. But the economic setting for and societal attitudes about higher education have changed dramatically, particularly in the past two to three years. These changes have created the need to build a new framework for our climb—one that is likely to be pervasive and enduring.

In some respects, our task is easy to articulate. First, there must be constant renewal and enrichment of WPI's faculty. Second, the settings in which faculty conduct their activities must be functional and up-to-date (especially for programs in science and technology). And third, the faculty and the settings must appeal to an increasingly discerning but limited market—prospective students.

Faculty and students, of course, can and do speak for themselves. Settings—buildings and facilities—cannot. Together, though, these three interrelated consumers of funding must be kept in dynamic equilibrium. Satisfying one more optimally than the others will lead to an imbalance and, in the long run, to a less attractive institution.

It is becoming impossible to satisfy fully this triad of faculty, plant and students, largely because there are too few donors right now with the necessary wherewithal and disposition. As providers of life support to our climbers, we therefore must work on the most compelling and the most enduring objectives for the longer run by building WPI's endowment. At the same time, we must pursue current funding to fill in the outer edge of the annual institutional budget—what has often been referred to as the "2 percent margin for excellence."

If you will, endowment builds for the future, while funds for the operating budget support the present. Success in both support streams is essential if WPI is to be the place that all of us want it to be—now and in the years ahead. (Figure 1 shows the market value of the WPI endowment over the past 14 years; Figure 2 shows the growth of the total endowment

FIGURE 1. MARKET VALUE OF THE WPI ENDOWMENT

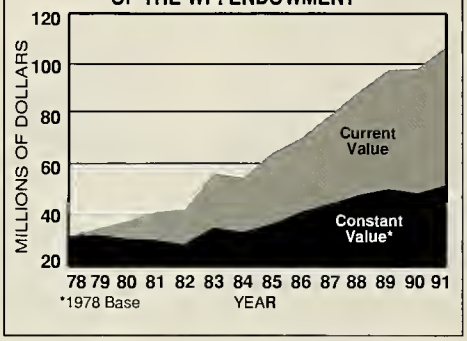
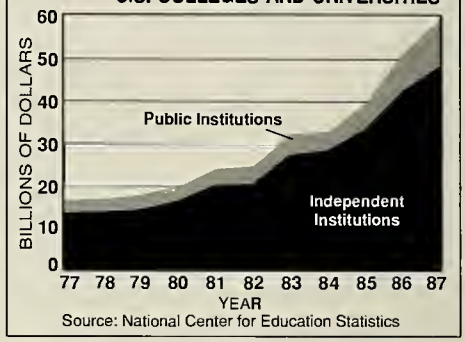


FIGURE 2. TOTAL ENDOWMENTS FOR U.S. COLLEGES AND UNIVERSITIES



Source: National Center for Education Statistics

TABLE 1. ENDOWMENT STRENGTH

Some Representative High-Quality Liberal Arts Colleges

	Millions of Dollars	Total Student Enrollment	Endowment Per Student
Amherst	$269	1,584	$169,800
Grinnell	287	1,373	209,000
Middlebury	228	1,950	116,900
Oberlin	245	2,971	82,465
Pomona	296	1,392	212,600
Smith	342	3,673	93,100
Swarthmore	336	1,300	258,460
Wellesley	374	2,214	168,900
Wesleyan (CT)	271	2,863	94,650
Williams	333	2,177	152,960

Some Representative Institutions Similar to WPI *(Principally Science and Technology)*

	Millions of Dollars	Total Student Enrollment	Endowment Per Student
Caltech	$467	1,821	$256,450
Carnegie Mellon	299	7,090	42,172
Harvey Mudd	68	563	119,893
Lehigh	260	4,562	56,993
MIT	1,404	9,536	147,232
RPI	230	6,556	35,082
Rice	1,068	4,220	253,080
Stevens	52	3,120	16,540
WPI	98	3,970	24,736

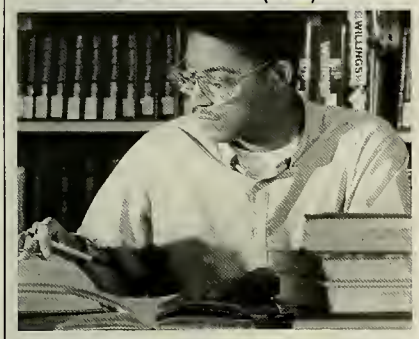
Source: *Voluntary Support of Education 1990*, Council for Aid to Education (CFAE)

Table 2. Some Representative Changes in Assets, Revenue and Expenditures at WPI

	FY1985* (in millions of dollars)	FY1991* (in millions of dollars)	Change (in percent)
Endowment	38.2	51.3	34.3
Tuition/Fees Revenue	12.4	18.3	47.6
Total Revenues	27.3	32.7	19.7
Instruction & Library	7.8	10.1	29.5
Financial Aid	3.9	6.3	61.5
Operations and Plant Maintenance	2.2	2.2	0

*Constant dollars, Basis: 1978 (Source: 1990-91 WPI Annual Report)

Figure 3. Alumni Scholars Minicampaign (1989)



The Objective: Endow a new undergraduate scholarship fund representing the pooled gifts of alumni and friends.

The Challenge: Howard G. Freeman '40 and Robert H. Beckett '57 each pledged $100,000 to launch the fund.

The Audience: 8,000 alumni (an equal number of prior student-grant recipients and randomly selected non-grant recipients). Individuals with outstanding pledges to the *Campaign for Excellence* were excluded.

Donors: 1,172.

Total Pledged: $229,959 (exclusive of matching gift monies). (This campaign is ongoing.)

for U.S. colleges and universities over a similar period; Table 1 compares WPI's endowment strength to that of several other institutions.)

The WPI Alumni Fund has provided, and continues to provide, much of those needed current dollars. Including donors' corporate matching funds, but less the major Reunion class gifts (usually directed to specific capital purposes), Alumni Fund contributions account for about 10 percent of our fund-raising results. However, the remainder of this article concerns the need to balance off fund raising for one-of-a-kind projects, such as the renovation of a campus building, and the enhancement of our institutional resources with endowment building.

Most one-of-a-kind projects are either thoughtfully planned (and often postponed!) or opportunistic. The former are often easier to manage from a development perspective, but the latter are often more seductive. We know, for example, that roofs have a certain lifetime; they must be continually repaired and occasionally replaced. Buildings must be painted—inside and out—to preserve their structural and aesthetic value. And from time to time, they may undergo interior space reconfigurations to make better use of existing space. These are planned events.

Opportunistic projects come about when a new faculty member or a group of faculty get together to create a new course, curriculum or research project. Specialized equipment, dedicated space—usually with some particularly novel configuration—and new or enhanced support services are elements of opportunistic fund raising. That is, they arise somewhat unexpectedly—and opportunities come and go quickly—so speed is often of the essence.

As an example of a planned project, we are currently completing a full interior refurbishment of Alden Memorial, its first in about a half-century of service. The project, which includes adapting existing space for better usage, will cost $2.7 million (roughly four times the original cost of the building). Currently, we are putting together the funds needed to create upgraded facilities for mechanical engineering in Higgins Laboratories and Stoddard Labs. Higgins is of the same vintage as Alden Memorial, and it, too, will be getting its first major overhaul. The price tag for installing an elevator, replacing rotted nails that hold up the roof slates, significantly enhancing power and other services, and reconfiguring space for more modern usage will amount to at least $5 million.

Worth pointing out is that these major interior renovations continue a long-standing tradition at WPI—ensuring that our historic (and hence aging) buildings are maintained to serve contemporary needs. So far we have renovated Boynton, Washburn and Stoddard, Salisbury, Atwater Kent, the Foundry (now the Project Center), and Alden Memorial. When the Higgins restoration is completed, our only truly "old" academic building left to do will be Stratton.

But let me get to the essence of the climb before us. One-of-a-kind and opportunistic projects have some unique characteristics. For example, they can be postponed, neglected or deflected, but doing so too often will lead eventually to a physically impoverished institution, one that is no longer attractive to the very people who make it what it is today. To avoid that fate, we must build our endowment—aggressively—along three broad fronts:

Endowing Financial Aid

Given what WPI is facing, its endowment is inadequate—though not woefully—for the long term. For example, our current expenditures for undergraduate financial aid roughly equal the income available from our $110 million endowment. (The Board of Trustees' "spending rule" permits the Institute to put 5.5 percent of the average market value of the endowment for the previous two fiscal years toward current operations.)

The Trustee Investment Committee is vigilant in maintaining an "aggressively prudent" posture in endowment investments, and it should continue to do so. But while the financial aid example above is a bit misleading, since only a portion of the money we allocate to student aid comes from endowment income, it does suggest that were we to try to fund student aid entirely on our own (unaided by resources such as ROTC scholarships), we would be able to do nothing else (beyond what we could raise money for directly).

We can help reduce the amount of the unrestricted endowment we now spend on student aid by building up an endowment specifically restricted to this purpose, though a look at Table 2 suggests that we have a ways to go before we reach a more secure plateau. About 65 to 75 percent of all engineering and applied science students enrolled at private institutions receive need-based aid. So unless we create new programs that might appeal to a more affluent constituency, our financial aid needs will not go away. And since future enrollment in programs that WPI currently offers is likely to come increasingly from minority families, our financial aid costs are likely to continue their upward spiral.

There is a bit of the chicken-and-egg issue here. A $1 million expenditure on financial aid will support about 20 high-

Table 3. DISTINGUISHED FACULTY ENDOWMENTS AT WPI

George I. Alden Chair in Engineering	(1970)*
Paris Fletcher Distinguished Professorship in the Humanities	(1985)
George F. Fuller Professorship in Mechanical Engineering	(1964)
Harold J. Gay Professorship in Mathematics	(1968)
Robert H. Grant Distinguished Professor of Entrepreneurship	(1988)
Weston Hadden Professor of Electrical Engineering	(1983)
John Woodman Higgins Professor of Mechanical Engineering	(1962)
Milton Prince Higgins Professorship in Manufacturing	(1988)
Leonard P. Kinnicutt Professorship	(1964)
Kenneth G. Merriam Professorship in Mechanical Engineering	(1977)
Morgan-Worcester Distinguished Instructorship	(1974)
Walter and Miriam B. Rutman Professorship in Chemistry	(1986)
Joseph Samuel Satin Distinguished Fellowship in Electrical Engineering	(1982)
Russell M. Searle Instructorship in Mechanical Engineering	(1978)
John E. Sinclair Professorship in Mathematics	(1915)
Harry G. Stoddard Professorship in Management	(1982)
The White Family Professorship (at-large)	(1987)

*Year of Establishment

Table 4. ENDOWED GRADUATE FELLOWSHIPS AND ASSISTANTSHIPS AT WPI

Arvid and Marietta Anderson '20 Fellowship

Robert H. '08 and Esther Goddard Fellowship

John C. Metzger Jr. '46 Teaching Assistantship (Chemical Engineering or Chemistry)

Norton Company Fellowship (Mechanical Engineering)

Robert S. Parks 1893 Fellowship

Carl '11 and Inez Weidenmiller Fellowship

Helen E. Stoddard Fellowship in Materials Science

Ralph E. Spaulding '09 Fellowship (Structural or Construction Engineering)

need students for four years. A like expenditure in programs or facilities, on the other hand, will have a direct and lasting impact on institutional quality. Still, without good students there would be no need for enriched programs, and vice versa.

Some of our readers will recall being invited in 1989 to support the new Alumni Scholars Endowment (Figure 3). Since few donors can afford to contribute the minimum of $50,000 it requires to endow an individually named scholarship, the Alumni Scholars Endowment is an ideal way for donors to commingle their smaller gifts to build what I hope will be a major income stream for future generations of WPI students. Incidentally, about $22.2 million of our endowment currently consists of gifts restricted to financial aid. We would need about $175 million (in current dollars) to cover our current student population!

Program Maintenance and Enrichment Endowment

The creation of distinguished professorships and graduate fellowships and assistantships is a popular and important way for colleges and universities to enhance their endowments. This type of endowment secures a growing share of an institution's instructional costs—in perpetuity—helping to insulate the institution against ups and downs in student enrollment and periods of economic stress. Therefore, not only do named chairs help recruit and retain the ablest faculty, they can relieve the pressure on operating budgets.

In fact, while such chairs were once "add-ons" to faculty counts, more and more they are being used to help in budget relief. If you were to survey the nation's most distinguished institutions, you'd find that restricted endowment building for this objective is growing apace. In fact, at some of the richest institutions, you'd discover that about 25 percent of faculty members either hold endowed chairs or receive much of their compensation from endowment restricted to faculty and instruction.

Some $7.9 million of WPI's endowment is currently restricted to faculty chairs. In addition, $3.6 million was pledged during the *Campaign for Excellence* for this purpose (Tables 3 and 4). I'm pleased that six endowed chairs and eight fellowships and assistantships were generated during the *Campaign*, but we need a great many more—of both. (One day I hope we have a distinguished endowed professorship named in honor of Robert H. Goddard '08; Princeton and Caltech do!) In addition, there are open opportunities at WPI for endowing the positions of provost, undergraduate and graduate deans, academic department heads, head librarian, athletic director, and so on. We are limited only by the interest and imagination of our prospective donors!

Building Trusts

I've saved the hardest for last, for here the climb requires sturdy legs. The need to build endowments for financial aid and the faculty are obvious and well-understood. Without students and faculty, there would be no institution, and if either is substantially undernourished, the quality of our outcomes—educated young men and women—will not command the support of our most promising future donors. But our buildings and facilities play an equally vital role in the success of the Institute.

When Yale University decided to commit a more significant portion of its annual operating budget and future fund-raising efforts to rebuilding its long-neglected physical plant, President Benno Schmidt suggested that it wouldn't be Yale were the university to conduct its educational programs in tents. Vartan Gregorian, president of Brown University, recently expressed a similar sentiment. Facing growing pressure to increase spending for financial aid (Brown currently provides aid for 38 percent of its student body), Gregorian noted that if Brown were to respond to that pressure and neglect the other things that make it an attractive institution—things like the campus and the faculty—Brown would not remain an attractive place for future students.

Repairing roofs, repointing brick facades and painting classroom walls are hardly seductive fund-raising targets. And because buildings don't talk, they are often neglected or forgotten, as financial resources get stretched to cover other growing human needs and opportunities.

Universities and colleges mean many things to many people, but the appearance of the physical plant is often a common denominator. While graduates may look back fondly on notable or caring faculty members, on friendships gained, on time spent in intercollegiate athletic competition, or on the challenge of mental confrontation, they almost always remember the beauty of the campus as it was in their day. Current students, faculty and staff want the environment in which they spend much of their waking hours to be attractive and well-equipped. Prospective

students, faculty and staff want to know that the campus is inviting and up-to-date, and that the library collections, computer facilities, and out-of-class environments convey a sense of institutional strength.

A growing number of institutions will no longer erect new academic space unless there is an up-front endowment to maintain that space. In one of its many wise and enlightened programs, The Kresge Foundation focused upon a unique subset of this issue—keeping teaching laboratories in the sciences current. WPI was one of several institutions to receive a challenge grant from Kresge's Science Laboratory Initiative. The $325,000 grant challenged us to raise $1.3 million for an endowment that will keep current our new Bioprocess Science and Technology Laboratory, located in the 102-year-old Salisbury Laboratories (Figure 4).

In the narrow sense, the foundation required us to make a major commitment to ensure the currency and usefulness of the laboratory in the years to come. In the larger sense, though, it reminded us that as a science- and technology-driven institution, we must think not only about maintaining our buildings, but what goes on within those buildings. One of our trustees, S. Merrill Skeist '40, put it well when he said a modern laboratory is like a precision machine; both need substantial care and continuous investment if they are to remain useful.

So what we are embarking upon is a special climb to create minimum endowment-maintenance funds, first for our historic buildings—Boynton, Washburn and Stoddard, Salisbury, Atwater Kent, and Stratton—and then for all our academic buildings—Higgins, Olin, Goddard, Kaven, Fuller, Gordon Library and Alden Memorial. Worth pointing out here is that most of our academic-use buildings (Higgins, Gordon Library and Harrington Auditorium are major exceptions) were the gifts of friends, not alumni. At the very least, we owe it to their memory to care for these structures.

Long before we thought of doing this, one discerning donor started a maintenance fund for Harrington Auditorium. That donor still contributes to the fund each year, and has already built up nearly $300,000 for this important initiative.

Properly endowed, maintenance funds will enable WPI to keep all of its academic buildings in full repair (Table 5 includes target endowments for each building).

Figure 4. BIOPROCESS LABORATORY MINICAMPAIGN (1990)

The Objective: Help raise $1.3 million to create a permanent maintenance endowment for the Institute's new Bioprocess Technology Laboratory.

The Challenge: The Kresge Foundation pledged $325,000 toward the construction of the lab if WPI could raise the funds for the endowment.

The Audience: 6,000 alumni and parents, including biology and life sciences majors, and alumni with little or no giving to WPI since 1986. Individuals with outstanding pledges to the *Campaign for Excellence* were excluded.

Donors: 1,320 alumni and 1,056 parents.

Total Pledged: $347,248 (exclusive of matching gift monies). $171,876 was from alumni and $175,372 from parents.

(This campaign has been completed.)

However, it should be noted that our intent is not to provide funds to retrofit any building for new uses; that would fall under the heading of a "one-of-a-kind" project. We've called this new, highly important endowment initiative Building Trusts, and have designed a special logo (Figure 6) to identify it.

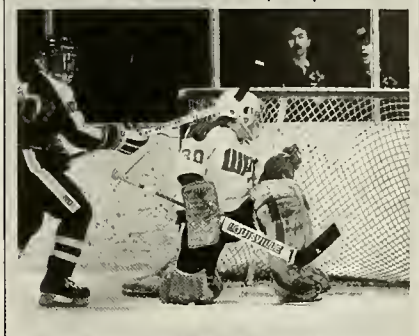
Much like the financial aid and academic chairs and fellowship endowments, Building Trusts will create an additional, growing component of our endowment, making deferred maintenance less dependent on funds from the operating budget. In a sense, we'll be giving our buildings a voice of their own.

In summary, our key objective for the next several years will be to build our endowment to provide the resources needed to enable WPI to remain the special place it has been for so many of us. While our current resources are the envy of many lesser institutions, we still have a long climb to ensure that they can place us among the very best. And you know, I just happen to think that that is where those who will make a difference want us to be.

—Donald F. Berth '57

Berth is vice president for university relations.

Figure 5. ATHLETIC ENDOWMENT MINICAMPAIGN (1991)



The Objective: Create an endowed fund to help sustain an excellent and diverse athletics program for all students.

The Challenge: George T. Abdow '53 pledged $1 for every $2 raised, up to $100,000.

The Audience: 8,000 alumni and parents, including all Poly Club members, participants in club, intramural, recreational and varsity athletics, and nonathletes whose cumulative giving for the previous three years was below $100. Individuals with outstanding pledges to the *Campaign for Excellence* were excluded.

Donors: 890 alumni and 655 parents.

Total Pledged: $176,478 (exclusive of matching gift monies). $109,962 was from alumni and $66,516 from parents.

(This campaign is ongoing.)

Table 5. BUILDING TRUST ENDOWMENTS FOR MAJOR ACADEMIC/CAMPUS BUILDINGS*

Alden Memorial	$1,630,000
Atwater Kent Laboratories	2,165,000
Boynton Hall	1,230,000
Fuller Laboratories	3,790,000
Goddard Hall	2,450,000
Gordon Library	2,390,000
Harrington Auditorium	3,035,000
Higgins Laboratories	2,055,000
Kaven Hall	1,235,000
Olin Hall	1,315,000
Salisbury Laboratories	2,565,000
Stratton Hall	745,000
Washburn/Stoddard	1,465,000

*Basis: Endowments that earn 5.5% (under WPI's "spending rule," income available for current operations equals 5.5% of the average market value at close, June 30, for the previous two years). Each building's maintenance is calculated at 2% of its current replacement value.

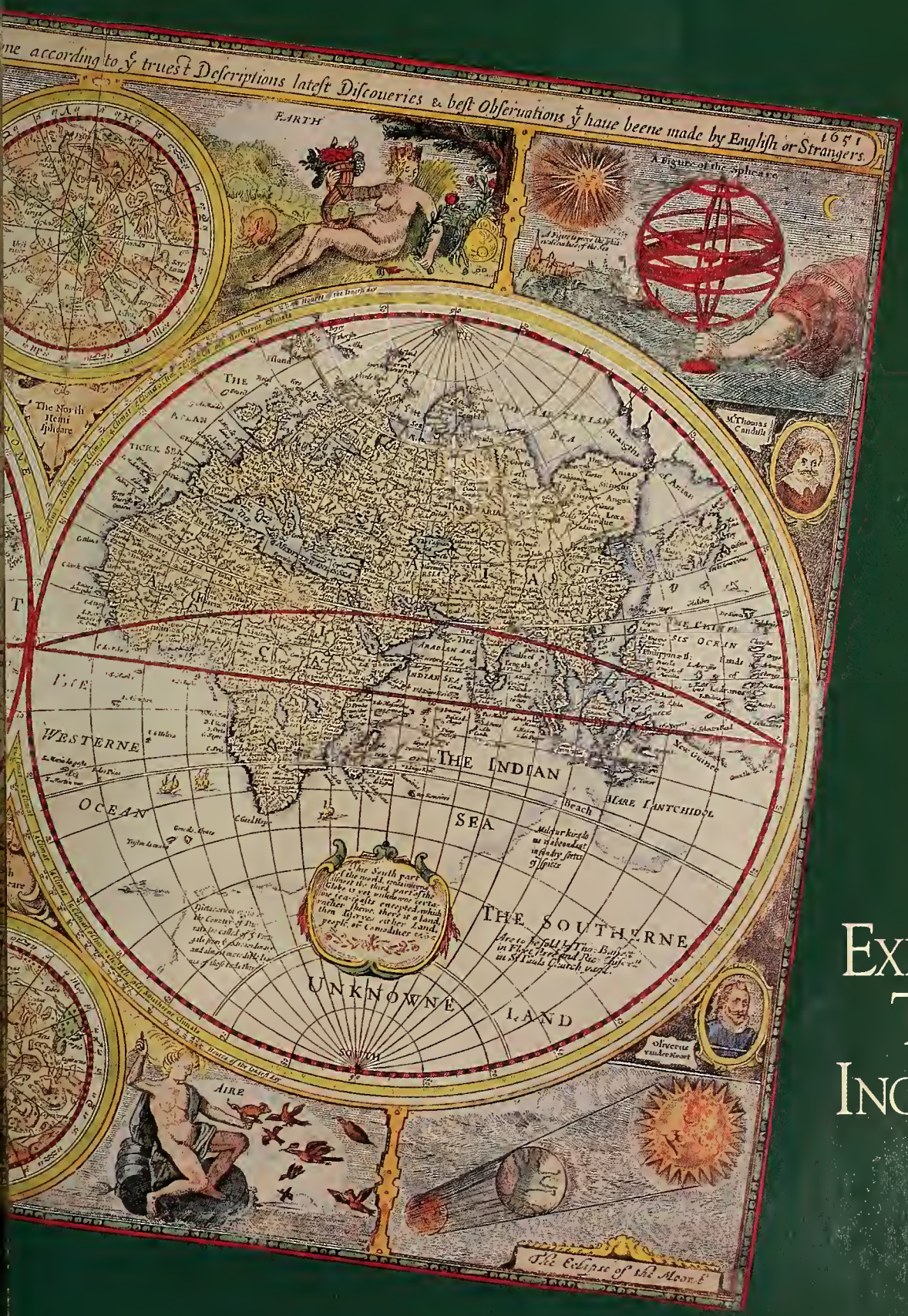
Figure 6.

BUILDING TRUSTS AT WPI

WPI Journal

WORCESTER POLYTECHNIC INSTITUTE

SPRING 1992



Exploring Terra Incognita

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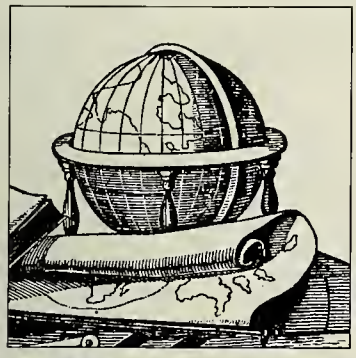

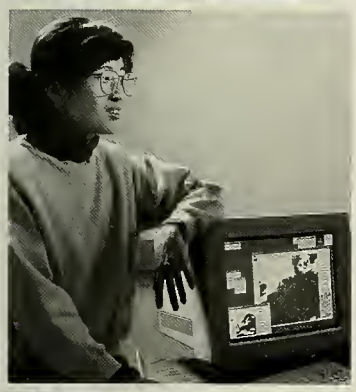

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On the Cover: The world as it was known to 17th century explorers. Story on page 4. Map courtesy of Hammond Inc. **Opposite:** An undergraduate finds a quiet spot among the stacks in Gordon Library to explore a book. Story on page 27. Photo by Janet Woodcock.

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In Praise of Discovery

"The world we now view from the literate west—the vistas of time, the land and the seas, the heavenly bodies and our own bodies, the plants and animals, history and human societies—had to be opened for us by countless Columbuses. In the deep present they emerge into the light of history, a cast of characters as varied as human nature. Discoveries become episodes of biography, unpredictable as the new worlds the discoverers opened to us."

JOSEPH H. BAILEY, NATIONAL GEOGRAPHIC SOCIETY, COPYRIGHT 1989

With those words, Daniel J. Boorstin began his monumental 1983 study, *The Discoverers*. This year, as we observe the 500th anniversary of Christopher Columbus' first voyage of discovery to what would come to be called the New World, it seems fitting that we turn our attention to the men and women who have followed in the footsteps of the great explorers, scientists and inventors. They have pushed back the boundaries of the known and shed light on the unknown; and like the protagonists of the popular television series *Star Trek*, they have gone where no one has gone before.

In tribute to this pioneering spirit, WPI devoted its 124th Commencement exercises on May 23 to the theme, "Discovery: Seeking Answers to the Unknown." The theme provided an opportunity to recognize a number of individuals who have earned the title "discoverer." They included Jane E. Shaw, president and chief operating officer of ALZA Corp., a world leader in the development of innovative drug delivery systems.

Shaw, who received her bachelor's degree and doctorate in physiology from the University of Birmingham in England, spent the years between 1964 and 1970 at the highly-regarded Worcester Foundation for Experimental Biology, where she conducted research on prostaglandins, cyclic fatty acids that act like hormones in the body, helping regulate blood pressure and aiding in the contraction of smooth muscle. She joined ALZA in 1970 and assumed her current post in 1985. A holder of seven patents and the author of more than 100 papers in scientific journals, she is also known for her research in gastric physiology and the transdermal permeation of drugs.

Commencement speaker Robert D. Ballard may embody more fully than most the true spirit of the discoverer. Born in Wichita, Kan., he earned a bachelor's degree in geology and chemistry at the University of California at Santa Barbara. He attended graduate school at the University of Southern California, the University of Hawaii, and the University of Rhode Island, from which he received his Ph.D. in marine geology and geophysics.

Today, Ballard is a senior scientist in the department of applied ocean physics and engineering and director of the Center for Marine Exploration at the Woods Hole Oceanographic Institute. It is in his capacity as marine explorer that Ballard has captured the imagination of millions around the world.

Ballard has led or participated in 50 deep-sea expeditions, exploring the world under the sea in such submersibles as *Alvin, Trieste II* and *NR-1*. On one of those expeditions, mounted in 1974, Ballard rode in the cramped, dimly lit sphere inside *Alvin* nearly two miles beneath the Atlantic—the same ocean Columbus crossed nearly 500 years before—to get the first close-up look at the mid-ocean ridge.

Like a 46,000-mile seam that rings the world, splitting the seabed beneath most of the world's oceans, the mid-ocean ridge is the source of the phenomenon known as continental drift. Searing hot lava emerges from this rift in the sea bottom, adding to

JOSEPH H. BAILEY, NATIONAL GEOGRAPHIC SOCIETY, COPYRIGHT 1989

Opposite, technicians prepare to send a small robotic submersible called *Medea* below on a Jason Foundation expedition. Left, aboard the research ship *Star Hercules*, Robert Ballard points to an image of the German battleship *Bismarck* sent up from the deep by *Argo*.

the sea floor and pushing apart the plates on which the continents ride. In fact, were he to make his voyage today, Columbus would have to sail a bit farther—about 30 feet—because of seafloor spreading.

Because measurements of the temperature of the ocean floor near the mid-ocean ridge showed that the rock there was cooler than it should have been, given the relatively short (in geological terms) period it had had to cool, scientists had theorized that cold seawater must somehow penetrate the crust, pick up heat, and bring it back to the surface. But no one had ever seen the vents from which this hot water must reemerge.

In 1977 Ballard organized an expedition to a deep ocean rift near the Galápagos Islands in the Pacific Ocean. An unmanned vessel called *Angus* was sent down to find and photograph any sources of unusually warm water. When the film was processed, Ballard and his fellow scientists were startled to see a strange world populated by giant, foot-long clams. When he dove to the vents himself inside *Alvin*, Ballard found that tube worms, rattail fish, anemones and crabs also live in this community, which thrives thousands of feet deeper than the last ray of sunlight can penetrate.

Analysis of the water pouring forth from the vents provided the answer to how these creatures survived in an environment that should have been devoid of life. The water was chock full of hydrogen sulfide (the gas that gives rotten eggs their foul odor) and bacteria. The bacteria metabolized the hydrogen sulfide. In the process they converted carbon dioxide in the water to organic carbon compounds. The bacteria, in turn, became food for the community of vent animals.

On a 1979 dive to the East Pacific Rise off the coast of Mexico, Ballard and his crew became the first people to observe "black smokers," chimneys formed from iron, zinc, copper sulfides and silver that belch forth jets of black water hot enough to melt lead. The flow of dissolved minerals from the black smokers and the warm-water vents may explain how the ocean became so salty, a mystery that has long eluded scientists.

Ballard may be best known for his discoveries of the *R.M.S. Titanic* in 1985 and the German battleship *Bismarck* in 1989. Both ships were extensively explored by submersibles, including *Argo*, an unmanned vessel loaded with video cameras and lights, and *Jason Junior (JJ)*, a small robotic platform attached to Argo by a tether that can explore and photograph places that are too risky for *Argo*—including the interior of the *Titanic*. The high-resolution pictures sent back by these machines painted haunting portraits of these once-proud ships.

After the *Titanic* expeditions, Ballard received hundreds of letters from schoolchildren seeking information about how he found and explored the ship. In 1989 he established the Jason Foundation for Education to bring the excitement of undersea exploration directly to youngsters around the nation. Using the power of satellite communications, Ballard has taken more than 500,000 schoolchildren with him on explorations of a fourth-century Roman shipwreck in the Mediterranean, sunken ships from the War of 1812 in Canada's Lake Ontario, and the Galápagos Islands.

Named for the mythological Greek explorer who discovered the Golden Fleece, the foundation has established primary interaction sites (PINS) at several locations around the country. One such site was set up in 1991 at the New England Science Center in Worcester. Each PIN received a command center that recreates the control station on Ballard's ship from which *Argo* and *Jason*, the successor to *JJ*, are controlled. Students at PINS can watch the underwater explorations live on large television monitors. At a few sites, including the New England Science Center, students can even fly the underwater robots.

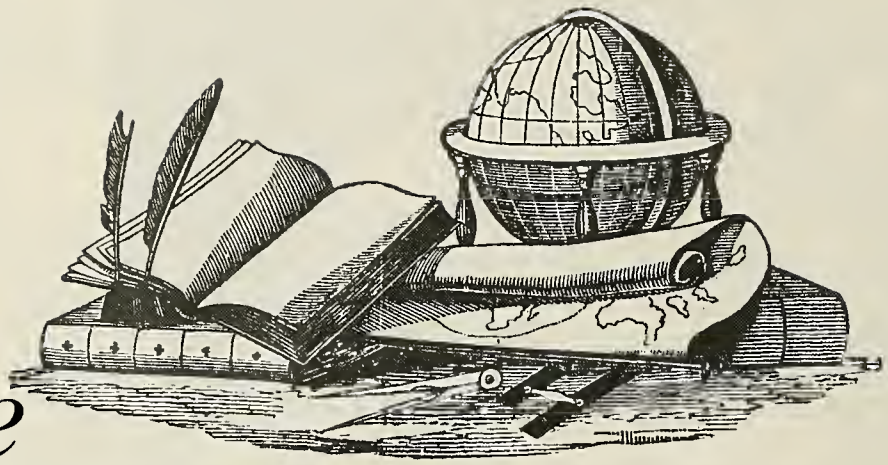
Throughout his career, Ballard has been driven by an almost primal urge to see what no one else has seen, to find the answers that have eluded others, and to broaden our understanding of the world in which we live. That motivation has nudged many WPI alumni into successful careers as scientists and inventors. In the pages that follow, you will meet several of them. Two, acoustical oceanographer Herman Medwin '41 (page 7) and entrepreneur Dean Kamen '73 (page 32), joined Ballard and Shaw on the platform at Commencement recently to receive honorary degrees.

In this issue you will also meet Caleb Hammond '37, chairman of Hammond Inc., one of the nation's largest publishers of maps and atlases. Most of us have taken voyages of our own across strange lands and seas by delving into the pages of the family atlas. It may be no coincidence that Columbus himself was a cartographer before he convinced Queen Isabella to fund his first trip across the Atlantic. The desire to explore and map the unknown is very likely a basic element of human nature, one that burns in all our hearts.

As they begin their careers, the WPI students who recently received their hard-earned degrees will find no lack of unanswered questions and uncharted waters. But, where once explorers were lured across oceans and deep into unexplored continents, today they may find themselves reaching out to the far side of the universe or into the very foundation of the atoms that make up everything we see.

"This is a story without end," Boorstin wrote. "All the world is still an America. The most promising words ever written on the maps of human knowledge are *terra incognita*—unknown territory."

—Michael Dorsey



The Discoverers

By Michael Dorsey

Five hundred years ago, Columbus set sail into unexplored waters in search of a new route to the Indies. While we remember Columbus this year, he was just one of countless human beings driven by the need to go where no one has gone before, to build what no one before has even dreamed of, and to understand what once evaded understanding. In the following pages are chronicled the stories of seven remarkable scientists and inventors who have listened to that inner voice that calls all of us toward the unknown — toward that unexplored region just beyond the horizon.

A Magnificent Career Driven by Imagination

During a career that has spanned more than four decades, C. Chapin Cutler '37 has often found himself squarely at the leading edge of the rapidly changing field of electronics. His inventions in radar and radio, telephone and television communications have earned him more than 80 patents and a worldwide reputation. "I don't think I'm really that smart," Cutler says as he looks back on those years. "I just think my imagination got turned on at an early age and that gave me tremendous motivation."

Cutler says he vividly remembers the moment his interest in radio caught fire. He was 14 and sitting around with friends at a summer camp not far from his home in Springfield, Mass. "This one camper had a yarn," Cutler says. "He said his brother had taken some old radio parts, built himself a transmitter, and used it to talk with people all over the world. I didn't believe a word of it."

But the story intrigued Cutler, who went to the Springfield Public Library to look for books on radio. The only one he could find was a massive tome by a Columbia University professor. Fortunately, a friend steered him to a popular pulp magazine that had an article on building a one-tube "junk-box" radio. With parts purchased at a local Goodwill store, Cutler assembled the radio, slipped on the earphones, and heard the dits and dashes of a Morse code signal from a station in Mexico City. He was hooked.

A short time later his father took him to a talk by a visiting scientist from the recently established Bell Telephone Laboratories. "The show was called 'The Wonders of Radio and Communication,'" Cutler says. "The guy modulated a neon bulb, talked over a light beam, popped corn with radio waves, and demonstrated inverted speech. I was on the edge of my chair. That's when I learned about Bell Laboratories, and that's when I decided what I wanted to do with my career."

Before he could work at Bell Labs, he needed an education, so he enrolled at WPI in 1933. His first concern, though, was not academics but money. Since his family could not provide financial help, he had to pay his own way. With the help of a young instructor of English named Paul Swan, Cutler found dozens of odd jobs, including cleaning windows and stoking the boiler in the president's house and tending the boilers on winter evenings at the home of Aldus Higgins (now called Higgins House).

Cutler began his WPI career as an electrical engineering major, but realized after his sophomore year that the electric power orientation of the curriculum wouldn't suit his needs. Against the advice of several of his professors, he and classmate Nathaniel I. Korman '37 became general science majors and designed their own course of study, including courses in advanced calculus and advanced physics.

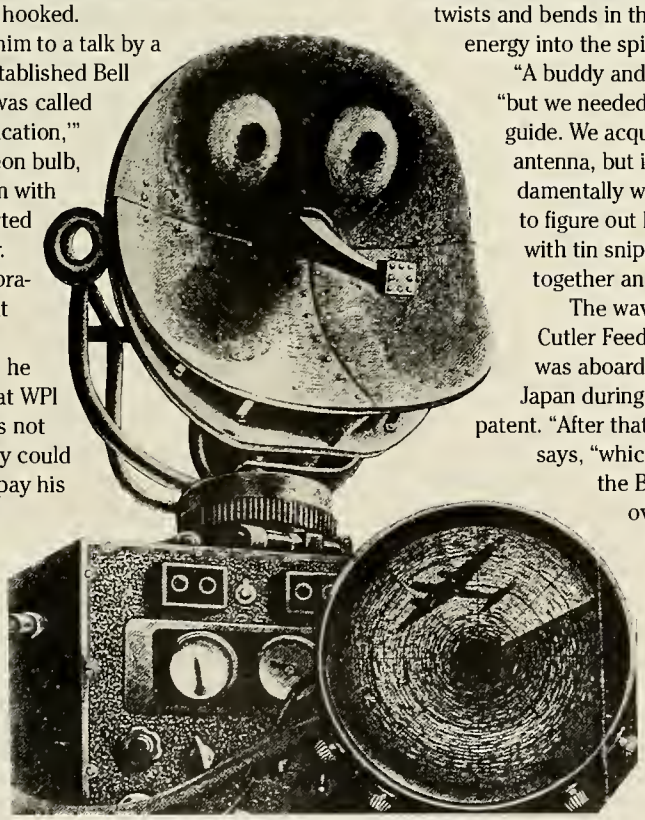
He was hired by Bell Labs shortly after his graduation in 1937. During his first week he met Ralph Bown, head of radio research, and it was, Cutler says, "a love affair. There's no doubt about it, he liked me as much as I liked him." The fatherly Bown took Cutler under his wing and assigned him to a project team that was designing a 12-channel transmitter to improve trans-Atlantic telephone communications. When that project was completed, he became involved in a crash, multi-corporation effort to design a radio proximity fuse for anti-aircraft shells. "That and radar won the Battle of Britain," Cutler remembers.

Radar, which was just being developed as Cutler joined Bell Labs, would become his next project. In the fall of 1941 he was asked to design the waveguide circuitry for a radar that would operate in the three-centimeter band (called the x-band). Because a radar antenna must continually rotate through a full 360 degrees, the antenna and the amplifier can't be connected by a wire or a fixed waveguide—a special conduit for the microwaves. Rotating joints and a series of twists and bends in the waveguide are needed to get the energy into the spinning antenna.

"A buddy and I engineered that well," Cutler says, "but we needed the antenna to terminate the waveguide. We acquired the design and reproduced the antenna, but it didn't work; there was something fundamentally wrong with it. I lay awake nights trying to figure out how to fix it. I went back to the lab, and with tin snips, ceiling wax and chewing gum, put together an antenna that worked."

The waveguide-antenna system, dubbed the Cutler Feed, was produced by the thousands and was aboard every allied bomber that flew over Japan during the war. It also earned Cutler his first patent. "After that I became known as an inventor," he says, "which meant that there was someone from the Bell Labs patent department looking over my shoulder for ideas. That's how I was able to get so many patents. A lot of them aren't worth the paper they're printed on. One invention that I am proud of is the corrugated waveguide, which was classified in this country for many years."

After the war Cutler's focus shifted to microwave amplifiers. He began by working on thermionic (triode) tubes adopted for microwave amplification. However, in 1944 news reached America of Rudolph



This rendering of the Cutler Feed appeared in *Time* magazine in 1945.

As one of the directors of Project Echo, Cutler started a tape of President Eisenhower's voice, which became the first signal sent coast to coast by satellite.

Kompfner's invention in England of the traveling wave tube. "It is a much better amplifier in most respects," Cutler says, "but much work and many inventions were crucial to making it practical."

In close collaboration with John R. Pierce, who would ultimately become executive director of research at Bell Labs, and Kompfner, who became associate director, Cutler contributed many inventions important to the success of the tube, which is now widely used in Earth satellite relay systems and in the military.

The launch of Sputnik in 1957 ignited the space race among the superpowers. A few years later the U.S. launched Echo I, an aluminized balloon 100 feet in diameter designed to study drag in the upper atmosphere. Bell Labs realized the satellite would make an excellent testing ground for satellite communications.

Partly under Cutler's direction, Bell Labs built a tracking station to monitor the satellite as it made its regular passes over North America. The station was the first to make use of a maser, a new kind of microwave amplifier that had revolutionary low-noise characteristics. A similar station was set up at the Jet Propulsion Laboratory Earth station in Goldstone, Calif., and the first radio transmission ever relayed in real time by satellite—a recording of President Eisenhower's voice—was bounced off the satellite during its first pass.

"I remember starting that tape with my own fingers," Cutler says. "It was probably the most exciting period in my life, because everything had to be done on the second. We had to have that antenna pointed exactly right, because this thing went whizzing from horizon to horizon in just 20 minutes."

After the first transmission, Bell Labs and the Jet Propulsion Lab scored other firsts, including the first telegraphy and facsimile transmissions by satellite and the first interactive voice conversation. "We were looking for scientific information, too," Cutler says. "For example: what is the transmission like, can you track the satellite, and is it reliable? For the first week, we didn't miss a pass. We were busy around the clock." Later, the Echo team served as technical advisors to Bell Lab Engineers who developed Telstar, the first successful active telecommunications satellite.

While Cutler says the Echo project was one of the most enjoyable of his career, the work for which he is best known began as a casual lunchtime conversation in the late 1940s with Bell Labs colleague William Goodall, who was applying pulse code modulation (PCM) to the transmission of television. The technique involved transmitting a television broadcast as short bursts, or pulses, of digital information.

Goodall had succeeded in digitizing the television signal, but Cutler saw an opportunity to use the digitization process to greatly reduce the amount of transmission capacity required for television (1,000 to 2,000 times the bandwidth needed for voice transmissions).

A television picture consists of thousands of picture elements called pixels. A picture is built up line by line as an electron beam scans back and forth across the television screen. A complete picture, called a frame, consists of two interlaced scans and is typically transmitted every 30th of a second.

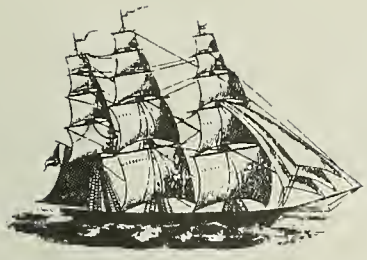
Cutler's idea stemmed from the fact that a television signal contains a high degree of redundancy. One picture element, line or frame is likely to be similar if not identical to the one that preceded it. In Cutler's scheme, instead of coding each sample separately, only the difference between the amplitude of a new sample and the quantitized or coded value of the previous sample is coded. Errors in sampling are compensated for in subsequent samples and the transmission requirements are greatly reduced. He named the technique differential PCM or DPCM. In later years, when large signal-storage systems became available, the idea was extended to include the correlation of lines and frames of a television picture.

One of Cutler's most important patents, DPCM received little notice for several years, but eventually the idea resurfaced and became generalized under the term predictive coding. Today, predictive coding is used in digital television transmissions, digital VCRs, fax machines, high-definition television, medical imaging systems and teleconferencing.

In 1963 Cutler became director of electronic systems research at Bell Labs. In 1971 he was promoted again to director of electronic and computer systems research. During these years he headed a research team that performed pioneering work into a new form of mobile radio that would pave the way for today's nationwide cellular telephone service.

Cutler's accomplishments as a scientist and inventor have earned him many honors over the years. A fellow of the American Association for the Advancement of Science and the Institute of Electrical and Electronics Engineers, he has received the IEEE's prestigious Edison Medal, Centennial Medal, and Alexander Graham Bell Medal. A member of the National Academy of Sciences and the National Academy of Engineering, he received WPI's Robert H. Goddard '08 Award for Outstanding Professional Achievement in 1982.

With no advanced degree, other than the honorary doctorate of engineering he received from WPI in 1975, he has taught Ph.D. candidates at Berkeley, Stanford and Caltech. He retired from Bell Labs in 1979 to become a professor of applied physics at Stanford. Today, as an emeritus professor, he says he tries to instill in his students the same love of discovery and fascination for technology that has driven him since that summer day more than 60 years ago when he first heard those strange and wonderful tales about radio.



Listening to Screaming Infant Microbubbles

Herman Medwin, center, and fellow professor O.B. Wilson, left, in 1990 with Rear Admiral Richard Pittenger, the "oceanographer of the Navy." Pittenger had been Medwin's student 25 years earlier.

If a raindrop falls in the ocean and no one is around to hear it, does it make a sound? The answer is yes, according to Herman Medwin '41, professor of physics at the Naval Postgraduate School in Monterey, Calif. The sound, he notes, contains a wealth of information that can help scientists gain a better understanding of such phenomena as weather, climatological change and global warming.

Medwin is a pioneer in the brand new field of acoustical oceanography, an outgrowth of underwater acoustics. While underwater acoustics, a science created in the wake of the *Titanic* disaster of 1912, uses natural sound and sound generated by manmade devices to locate objects, such as ships, submarines or icebergs, in or on the water, acoustical oceanography uses the characteristics of sound propagation and scattering in water to learn about the ocean itself.

Over the last decade or so, acoustical oceanographers have found ways to use sound propagation to answer a wide range of questions. For example, using techniques such as acoustical tomography, doppler sonar and side-scan sonar, acoustical oceanographers can measure the roughness of the ocean surface, study the characteristics of sediments on the sea floor, and measure the drift velocity of sediment carried along by ocean currents. By scattering sound off the air-filled swim bladders of marine organisms, they can track the migrations of fish and obtain counts of plankton and nekton far more accurately than with conventional methods.

In recent years, a major focus of acoustical oceanography has been microbubbles—microscopic spheres of air generated by breaking waves and raindrops. Until the mid-1960s, when Medwin first observed them, many scientists thought microbubbles could not exist in the ocean.

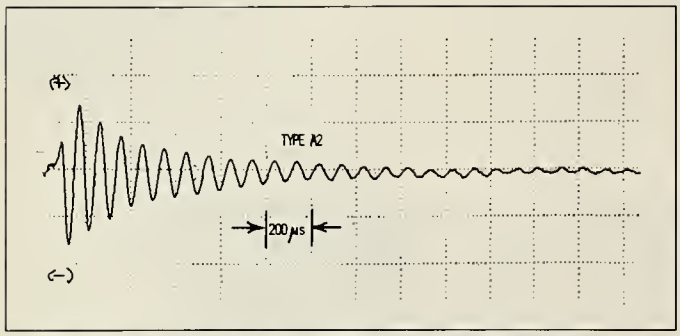
"Physicists had shown that a bubble will not last in a beaker of clean water," Medwin says. "Either the bubble pops to the surface and bursts, or the air gets squeezed out of it in just a few seconds. So the weight of evidence from the laboratory was that bubbles couldn't persist in the sea."

But Medwin knew these invisible bubbles had to be there. In 1964 he and fellow acoustician Clarence S. Clay, with whom he later wrote *Acoustical Oceanography*, the standard textbook in the field, postulated that there must be bubbles under a rough sea surface. His measurements showed that the many millions of bubbles generated by breaking waves persisted for long periods as bubble clouds that could be found as deep as 30 meters below the sea surface.

Medwin soon went back to sea with a laboratory device consisting of a sound source and a reflector separated by about a meter. After lowering the device into the water, he generated a burst of sound and observed it as it bounced back and forth between the sound source and the reflector.

Laboratory work and theory had shown that the frequency of sound absorbed by bubbles is directly related to their size—the larger the bubble the lower the frequency it absorbs—so, by measuring sound absorption over a wide range of frequencies, Medwin was able to make precise counts of the numbers of microbubbles of different sizes. "We found huge amounts of bubbles—just as we had predicted," Medwin says, "with radii ranging from 20 to 200 microns."

What makes it possible for the bubbles to persist, Medwin says, is



This plot shows the oscillating pattern of the sound produced by a "screaming infant microbubble." This pattern lets scientists identify the size of the raindrop that produced the bubble.

small particles of plankton, bacteria and dirt that adhere to their surfaces, preventing the air from being squeezed into the water. "In fact, bubbles are excellent scavengers," he says. "They ultimately drag this material to the surface, where it is deposited. Just as raindrops help to clear the atmosphere, bubbles help cleanse the ocean."

The junk that enables microbubbles to persist also made it difficult for optical scientists to verify Medwin's results for many years. Not all of the dirty bubbles generally show up in photographs, so most published counts were significantly lower than Medwin's until just a few years ago, when more sophisticated optical techniques—including one system that uses a laser to count the bubbles—became available.

When he first observed the bubbles more than 25 years ago, Medwin says he had no idea how useful they would become in the study of ocean phenomena. Part of their utility stems from their tendency to oscillate violently for several milliseconds after they are generated, emitting a loud, high-pitched sound. These "screaming infant microbubbles," as Medwin dubbed them, are like radio transmitters, sending out brief messages about the waves or raindrops that created them.

In recent years Medwin has made new measurements of microbubbles in the field, including measurements taken closer to the surface than any observations made before, and at lower frequencies than ever before. Using an 85-foot-high drop tower fashioned from a service shaft adjacent to his laboratory in Monterey, he has also begun observing how raindrops create microbubbles.

The measurements show that raindrops produce microbubbles in sizes proportional to their own size—in other words, large drops create large bubbles and vice versa. Since each bubble size has its own characteristic sound spectrum, the sound created by a microbubble is a precise indicator of the size of the drop that created it, Medwin says.

"This relationship enables you to dissect underwater sound. If you listen underwater when it's raining, you'll hear a tremendous roar, which is caused by the microbubbles. It sounds like a god-awful mess, but if you do a spectral analysis it turns out that different parts of the sound spectrum are caused by drops of different diameters. So you can tell the kind and quantity of rain that is falling and, by inference, the type of cloud cover."

Medwin has applied for a patent for this technique. He says he envisions a network of sonobuoys spanning the Pacific Ocean recording the sound of rainfall across a vast expanse of water for which

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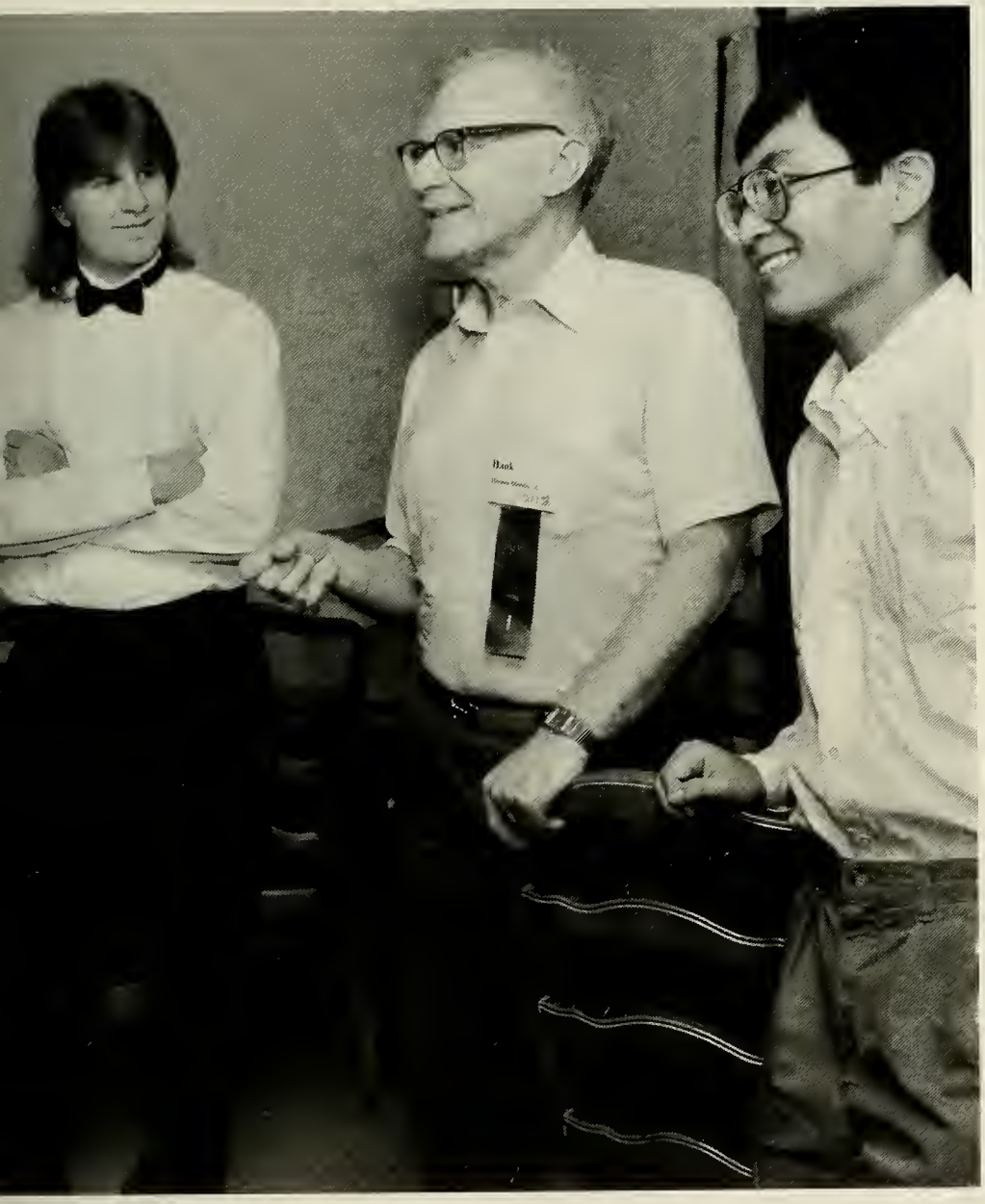
such data is sparse. More accurate data about rainfall over the oceans will help improve weather forecasts and enable scientists to create better models of the Earth's climate.

A better understanding of rainfall patterns over the ocean may also lead to a better appreciation of global warming, Medwin says. The oceans are important sinks for carbon dioxide, the gas responsible for the greenhouse effect that causes atmospheric warming. Like other atmospheric gases, CO_2 mixes with ocean water when rain and waves create bubbles. But without better data on oceanic rainfall, it is difficult to say how much CO_2 is making its way into the sea.

Studying the ocean was far from Medwin's mind when he earned his B.S. in physics from WPI in 1941. After working as a weather observer for the U.S. Air Force in Europe during World War II, he earned his Ph.D. in physics at UCLA. At that time, the university ran one of the foremost programs in acoustics, a subject that had long fascinated Medwin because of his love for the violin. (As a high school student, he was voted the best violinist in his hometown of Holyoke, Mass.)



At his 50th Reunion in 1991, Medwin, who has played the violin most of his life, was able to perform with the Medwin String Ensemble, which he established through a gift in 1987.

He taught at Los Angeles City College for six years and continued the work in nonlinear acoustics he had begun as a graduate student. He then worked briefly for an acoustical engineering firm, where he analyzed the noise of jet engines and wind tunnels. He also designed the ventilating towers for the Callahan Tunnel under Boston Harbor, assuring that the fans that pump car exhaust out of the tunnel would not disturb the surrounding neighborhoods.

In 1954, deciding he preferred teaching to consulting, he joined the faculty of the Naval Postgraduate School, where he has been ever since. "I knew nothing about the ocean then," he says, "but it was required that one teach courses in underwater acoustics because the Navy operates in the ocean and acoustics is how you find submarines."

Since then he has become one of the foremost researchers in his field. A recipient of WPI's Robert H. Goddard '08 Alumni Award for Professional Achievement and the Sigma Xi Distinguished Research Award from the Naval Postgraduate School, he is a fellow and president-elect of the Acoustical Society of America. And he is the author of more than 100 papers in scientific journals and holds several patents in acoustical oceanography.

When he is not working with students or writing up his latest research results, Medwin runs a consulting firm, Ocean Acoustics Associates in Pebble Beach. He also continues to indulge his love of music by playing violin with a string quartet every week. In 1987 Medwin, who performed with the Worcester Symphony Orchestra while he was a WPI student, gave WPI a gift with which it established the Medwin String Ensemble; he later provided another grant to create scholarships for WPI students who play string instruments.

"My capabilities never showed at WPI," he says, "at least not by the conventional measures used then. But there are other measures that are awfully important, and these include tenacity and imagination. It takes tenacity to study a string instrument and stick with it, and one needs imagination to perform and interpret music well. A scientist also needs those characteristics to be successful, but in reverse order—imagination to develop an idea and tenacity to see it through."

Making Photography Simple Took Complex Engineering

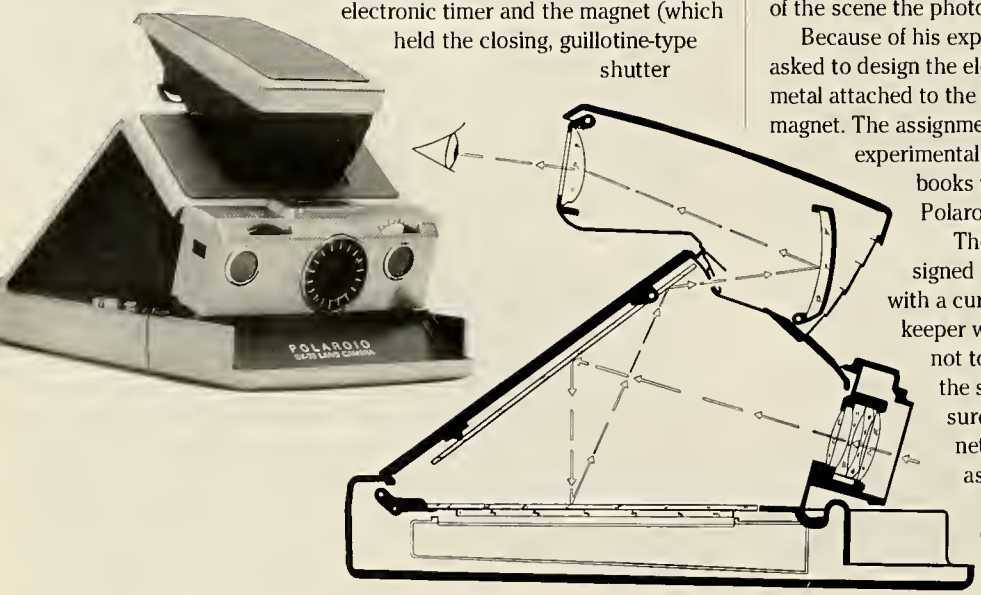
Edwin Land, inventor of the Land Camera and founder of Polaroid Corp., believed that the true value of a product could never be adequately measured by the cold, hard numbers of a corporate balance sheet. Instead, the worth of a piece of engineering, like the worth of a work of art, was in the elegance of its design and in the way it fulfilled the goals of its creator. "The bottom line," he once wrote, "is in heaven."

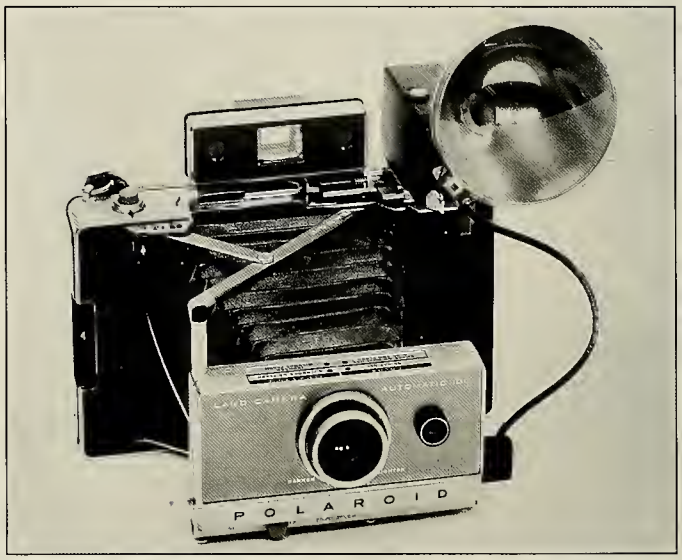
As he looks back on 26 years as one of Polaroid's chief designers, John P. Burgarella '50 seems to embody that creative spirit. Describing the intricate electronic mechanisms and the complex circuits he designed for Polaroid cameras and the revolution in instant photography he helped set in motion, what he remembers most is the beauty of the engineering itself and how his carefully crafted and tested electronic designs helped meet one fundamental goal—making photography a snap for millions of people the world over.

Burgarella, who received a bachelor's and a master's degree in electrical engineering from WPI, the latter in 1952, joined Polaroid in 1960 after working for eight years for Doelcam/Honeywell Corp. in Newton, Mass. While there he developed a DC amplifier that employed a magnetic modulator with no moving parts. Burgarella earned the first three of his 25 lifetime patents for the design.

His first assignment at Polaroid was designing a computer-controlled system for a machine that made pack film, a recent Polaroid innovation. In the summer of 1960 Polaroid introduced the Model 900, the earliest Land camera with an electrically controlled exposure system. The camera was a "mechanical nightmare," Burgarella says. Clearly, Polaroid needed a new concept.

The new concept was the Model 100, a design born in Polaroid's Applied Physics Laboratory. It would have a fixed-aperture lens and a shutter controlled by an electromagnet and an electronic timer. When the shutter button was pressed, the electronic timer and the magnet (which held the closing, guillotine-type shutter blade in place) were energized. At the same time, the opening shutter blade would be released, and a capacitor that timed the exposure would be unshorted.





PHOTOS ON THIS PAGE COURTESY OF POLAROID CORPORATE ARCHIVES

Opposite, John Burgarella with some of the revolutionary cameras he helped design for Polaroid, including the Model 100, above, the first successful electronic camera, and the SX-70, below, the first fully automated camera.

A photocell would regulate the amount of current delivered to the timing capacitor. The more light falling on the cell, the larger the current to the capacitor. The greater the current, the faster the capacitor would become charged and trigger a circuit that shut off the magnet, releasing the closing blade. The design ensured that the exposure time would be inversely proportional to the brightness of the scene the photographer was attempting to capture.

Because of his experience with magnetic devices, Burgarella was asked to design the electromagnet and the keeper, a small piece of metal attached to the shutter blade that would hold it firmly to the magnet. The assignment marked the start of months of design and experimental work that would ultimately fill dozens of notebooks with drawings, graphs, laboratory results and Polaroid photographs.

The tiny u-shaped magnet that Burgarella designed could lift more than three-fourths of a pound with a current of just two-hundredths of an ampere. The keeper was designed to be as light as possible, so as not to slow the shutter. Because precision timing of the shutter was critical to obtaining a correct exposure, Burgarella had to find a way to make the magnet release the keeper as quickly and as reliably as possible.

To do that, he designed a special circuit that quickly quenched the magnet. He also gave the keeper a curved face so only a small section of

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the metal bar made contact with the poles of the magnet. Since the air around the keeper was far less permeable to magnetic flux than the metal of the keeper itself, this curvature created what Burgarella calls a controlled air-gap that enabled the keeper to break away more quickly than if its entire face had touched the magnet. The design allowed precise exposures as short as 1/1,200th of a second.

The Model 100 was the first camera with an automatic flash. When a flashbulb unit was plugged into the shutter, it activated a circuit that selected a shutter speed so that just the right amount of light from the bulb reached the film. "A flashbulb output peaks at about 12 milliseconds," Burgarella says. "But if your subject is only a few feet away, you may need just 1/16th of the total output—about 4 milliseconds worth." To get such precise "chunks" of light, the closing of the shutter had to be carefully synchronized with the firing of the bulb.

While most of Burgarella's contributions to the Model 100 were to its electronic systems, he also did a careful mechanical analysis of the shutter to make sure the jolts caused by its opening and closing would not affect the operation of his magnet. This work resulted in several design changes, including a shock-absorbing bumper for the shutter. He also designed equipment to test his designs, helped set up the assembly line for the electronic systems at Texas Instruments, and designed test equipment for the shutter assembly line at Timex.

The electronic systems developed for the Model 100 became the basis for most of the electronic cameras marketed by Polaroid in succeeding years. By 1968 Burgarella had become manager of a small department. Like many Polaroid managers, he was aware that a small design team was working in carefully guarded secrecy on a revolutionary new camera system. "There were no electronics people in the group then," Burgarella says, "so they would occasionally come down and ask me questions without divulging any secrets. Eventually they said, 'We can't get along without this guy."

Burgarella gave up his department and became an individual contributor to what would become the SX-70, a fully automated single-lens reflex camera with a new type of film that developed right before the photographer's eyes.

The initial design called for electromagnets to operate the shutter, as they had in the Model 100. But after more than two years of work in that direction, the concept had to be abandoned because the single-lens reflex design required multiple operations of the shutter to accommodate both viewing the scene and exposing the negative.

Land decided to replace the magnets with solenoids. "This was a traumatic period for me because my wife had just been diagnosed with multiple sclerosis," Burgarella says. "Dr. Land knew I didn't like the idea of the solenoid shutter, but he wanted me to go along with it. He called me into his office and for the first 20 minutes all we talked about was my wife. He wanted to know what was going on and what Polaroid could do to help. It was only after that that he told me why he had really brought me in there. That's the kind of man Land was."

The SX-70 had several modes of operation. For example, when the film pack was inserted, the camera had to eject the film cover. Taking a flash photo required the camera to quickly (within a millionth of a second) determine which bulb in the flash bar was the next to be fired.

The most complicated mode was normal picture taking (see diagram, page 10). To take a photo, the camera had to close the shutter, release a spring-driven, double-sided mirror that covered the film pack, reopen the shutter to let light bounce off the mirror onto the negative, close the shutter, bring the mirror back down, process and eject the exposed print, and finally, open the shutter again for viewing.

Each mode of operation was controlled by an integrated circuit. While Burgarella designed the exposure-control circuits for all of the cameras before the SX-70, he says Polaroid did not have the expertise to create these complicated silicon chips. Instead, his team developed block diagrams and logic tables that showed exactly what the circuits had to do and when each event must take place. The chips were designed by Texas Instruments and Fairchild Semiconductor.

Power for the camera was provided by a custom-designed wafer-thin battery included in each film pack. Throughout the design phase, Burgarella held the unofficial title of "power czar," as it was his responsibility to make sure that the various devices that consumed power—from the solenoids, to the motor that ejected the film, to the flash bar—stayed within a maximum power budget.

Burgarella's work on Polaroid cameras earned him a number of awards and honors. In 1964, as a member of the small team that designed the Model 100, he received the Master Design Award from *Product Engineering* magazine. In 1984, WPI awarded him the Robert H. Goddard '08 Award for Professional Achievement, and he is currently a member of the Institute's Electrical Engineering Advisory Committee. In 1981, Polaroid conferred on him the honor of senior engineering fellow, a title that had previously been bestowed on just two other Polaroid engineers.

That title recognized more than two decades of fundamental contributions to technology that literally created the worldwide electronic camera industry and became the foundation for the success Polaroid has realized over the past three decades.

It was also a tribute to a job that took Burgarella far beyond the traditional role of inventor. "There was a lot more to my job than you might think," he says. "I had to be a manufacturing engineer, a test equipment engineer, a mechanical engineer, a manager and, at times, a diplomat. I could never be just an inventor."

Unraveling the Genetic Code for What Ails Us

For many years, scientists have known that clues to the causes of many human ailments are encoded in the enormously complex blueprint of the human genome. But it has only been within the past two decades that it has been possible to begin unlocking these secrets with the tools of recombinant DNA technology.

Armed with this newfound knowledge, doctors can now predict with great precision who may develop an ever-growing list of disorders, such as the fragile X syndrome, Duchene muscular dystrophy and cystic fibrosis, and who may pass these inherited diseases on to their children. Research in this new field, called molecular genetics, has provided exciting new approaches to identifying the causes of human disease and offers hope that someday it may be possible to treat—and perhaps prevent—many human ailments.

For Stephen N. Thibodeau '74, the revolution in medical genetics arrived at just the right time. Having long been interested in medical research, he studied chemistry at WPI and as a senior received a $5,000 grant from Saint Vincent Hospital in Worcester to develop an antero-venous shunt for use in intensive care patients. He earned his Ph.D. in biochemistry at the University of Washington in Seattle and completed a postdoctoral fellowship in clinical chemistry at the Mayo Clinic in Rochester, Minn.

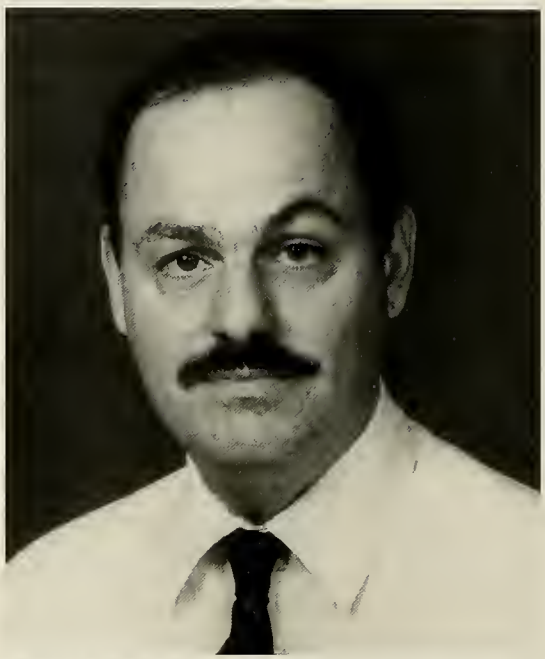
Those were the years when the power of recombinant DNA techniques was just being realized. The ability to literally chop up strands of DNA and identify the pieces, or genes, responsible for specific disorders would soon revolutionize the study of medicine.

In 1981, when Thibodeau became director of clinical chemistry at The Children's Hospital in Denver, Colo., he joined the revolution. His first project was to help locate the gene responsible for the fragile X syndrome, a condition that produces moderate to severe mental retardation in 80 percent of boys who have fragile X and less severe symptoms in about half of carrier girls.

Along with a number of others, Thibodeau used linkage analysis to close in on the location of the gene. Linkage analysis takes advantage of a phenomenon called crossing over, which occurs during meiosis, the type of cell division that produces sex cells—eggs or sperm. Humans have 24 different types of chromosomes. Two, the X and the Y, determine gender and are called the sex chromosomes (females have two Xs; males have an X and a Y). Normal human body cells have two copies of each of the remaining 22 chromosomes.

During meiosis, the two members of each chromosome type link up to form a pair. It is while the chromosomes are paired that crossing over occurs. A break develops in the same spot on each chromosome and the broken ends cross over and combine to form two somewhat different chromosomes. To understand how this works, imagine two ropes—one red and one blue. Both ropes are cut in the identical spot and the ends are recombined so there are now two ropes, each of which is partly red and partly blue.

Each chromosome is actually a long string of genes. The farther apart two genes are on this string, the more likely it will be that any one break will occur between them. When two genes are so close that they are virtually never separated by chromosome breaks, they are said to be linked. To locate a gene, scientists search for markers—sections of DNA with known locations—that are linked to the gene for which they are searching.



Stephen Thibodeau is using the latest advances in recombinant DNA technology to diagnose genetic disorders and chart the success of cancer treatments.

In Thibodeau's laboratory, linkage analysis, using several possible markers, was performed on DNA collected from the members of 30 families that have a large number of individuals affected by fragile X. These studies helped determine which markers provide a reliable means of identifying individuals with the gene, and also helped build a genetic map of the region around the gene.

"Once you've placed a genetic locus next to a known marker, the next step is to characterize that region in more detail," he says. As the genetic map for the region becomes clearer, scientists look for candidate genes and then hone in on the one actually associated with the disease. "There are a number of groups, including ours, that are using this approach to look at a host of other disorders."

Once a gene is isolated, Thibodeau says, scientists can begin to understand the underlying cause of the disease and the specific mutations—substitutions, deletions or insertions in the genetic code—that can occur within it.

Since 1987 Thibodeau has been director of the Molecular Genetics Laboratory at the Mayo Clinic. In that post he and his colleagues use the results of research similar to the fragile X project in one of three primary ways: to identify people who are carriers of genetic disorders, but who exhibit no symptoms themselves; to diagnose, while they are still well, people who carry genes for disorders that

do not appear until adulthood or people who have a genetic predisposition to developing cancer and other illnesses; and to spot serious genetic disorders prenatally.

"Recessive disorders, like cystic fibrosis and muscular dystrophy, are good examples of diseases for which carrier detection is important," Thibodeau says. "We may see a patient who has a sibling affected with muscular dystrophy. She is thinking of getting married and wants to know whether she is a carrier for the gene, and therefore what her chances are of having a child affected with the same disease."

One adult onset disorder that Thibodeau has been studying is familial adenomatous polyposis or FAP, an inherited predisposition to colon cancer that affects one in every 5,000 Americans. It is characterized by the early onset of colon polyps (affected individuals can develop several hundred to several thousand polyps). If they do not receive regular checkups to look for polyps, virtually all patients with the FAP gene will develop colon cancer and die from their disease. Recently, several groups of investigators have characterized the gene associated with FAP and Thibodeau's lab has developed a test to detect individuals who carry the specific mutations that are believed to cause the disorder.

Thibodeau has also been looking for the molecular genetic changes that are responsible for sporadic colon cancer. Although there is no obvious hereditary pattern for the sporadic form of colorectal cancer, Thibodeau says there is evidence that in most cases, individuals who have colorectal cancer may have a genetic predisposition to developing the disease. In fact, it now appears that a number of genes are involved in the process of tumor formation in colon cancer.

"The major part of our research," he says, "involves taking a close look at these chromosomes to see if we can find the genes that might be implicated in the process of developing cancer." Thibodeau says each altered gene may give a cell a specific advantage as it progresses from a normal cell to a polyp (a benign tumor) to a carcinoma to a deadly metastatic lesion.

The genetic tests Thibodeau hopes to develop for colon cancer will enable doctors to spot individuals who may have a strong tendency to develop the disease and also gain insight into how to distinguish the more aggressive tumors from other types. "The process involved in cancer formation is more complicated than the other genetic disorders we deal with and typically involves abnormalities in multiple genes," he says. "The clinical implications are enormous, however, given the large number of individuals affected by cancer each year."

In addition to identifying individuals who possess genetic disorders, the techniques Thibodeau uses in his laboratory can also help measure the success of treatments for specific diseases, especially cancers. One example is a type of leukemia known as chronic myelocytic leukemia or CML. This disease is thought to be caused by a translocation in which segments of chromosome 9 and chromosome 22 trade places.

The switch brings a proto-oncogene—a gene that can promote the growth of cancer cells—from chromosome 9 into proximity with the so-called bcr gene on chromosome 22. Together they form the code for a protein that appears to give leukemia cells a selective advantage. "It turns out that virtually 100 percent of patients with CML have the 9-22 translocation, which is known as the Philadelphia chromosome," Thibodeau says.

The 9-22 translocation is typically identified cytogenetically (that is, by staining the chromosomes and examining them under the microscope), though Thibodeau says molecular genetic techniques can spot the approximately 5 percent of CML cases that evade this type of analysis. More important, though, because these techniques can detect the presence of cells bearing the Philadelphia chromosome with great sensitivity—often as accurately as one cell in one million—they can serve as ideal warning systems for a relapse of CML after treatment.

The laboratory has also developed techniques for monitoring the success of bone marrow transplants, a treatment sometimes employed for leukemia—a cancer of the white blood cells that originates in the marrow. In this type of treatment, a recipient's bone marrow is removed and replaced with marrow from a carefully selected donor. Before the transplant, DNA from the recipient and the donor are analyzed—a process called DNA fingerprinting.

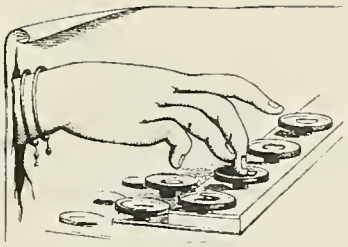
"Following the engraftment process, we look to see which cells are present," Thibodeau says. "We should see only cells with the donor's DNA in the marrow. If we see the recipient's cells, then presumably that means the leukemia is beginning to reappear."

COURTESY OF MAYO CLINIC

Laurie Doud prepares to analyze a DNA sample in the Molecular Genetics Laboratory at the Mayo Clinic in Rochester, Minn.

While the primary focus of Thibodeau's research is to characterize gene abnormalities and find ways to diagnose and treat individuals with genetic disorders like fragile X syndrome and colon cancer, he acknowledges that the long-term goal of the work he and other molecular biologists are doing is to pave the way for such not-so-futuristic techniques as gene therapy, in which defective genes are actually replaced with good genes, to keep people from getting diseases in the first place.

"Certainly, once we've found the gene for a disease, we want to take that one step further and find out how to treat and prevent the disease," he says. "There's no question that molecular biology and recombinant DNA techniques are having and will continue to have a profound impact on all facets of medicine. However, although we have made tremendous progress in the last decade, what we do not yet know about the human genome is staggering."



Pushing the Software Envelope

In his 1966 book, *Men, Machines and Modern Times*, Elting E. Morrison said, "The computer is no better than its program." Since his student days at WPI, Roger J. Heinen '73 has been creating programs that have helped make the computers they run on powerful, versatile and innovative tools—not to mention highly successful products.

From his 17-year career at Digital Equipment Corp., where he helped develop some of Digital's most critical and commercially successful software products, to his position today as the head of the Macintosh Software Architecture Division at Apple Computer, Heinen has continually found himself at the leading edge in software development. He credits much of his success in the rapidly evolving world of computing to the start he got at WPI.

Heinen was one of the first students to earn his bachelor's degree under the project-oriented WPI Plan. For his Major Qualifying Project he helped develop an automated class scheduling system. "It was classic computer science," he remembers. "We worried about the science of it and we didn't step back and ask ourselves how hard it was going to be to implement and how long it was going to run once it was started."

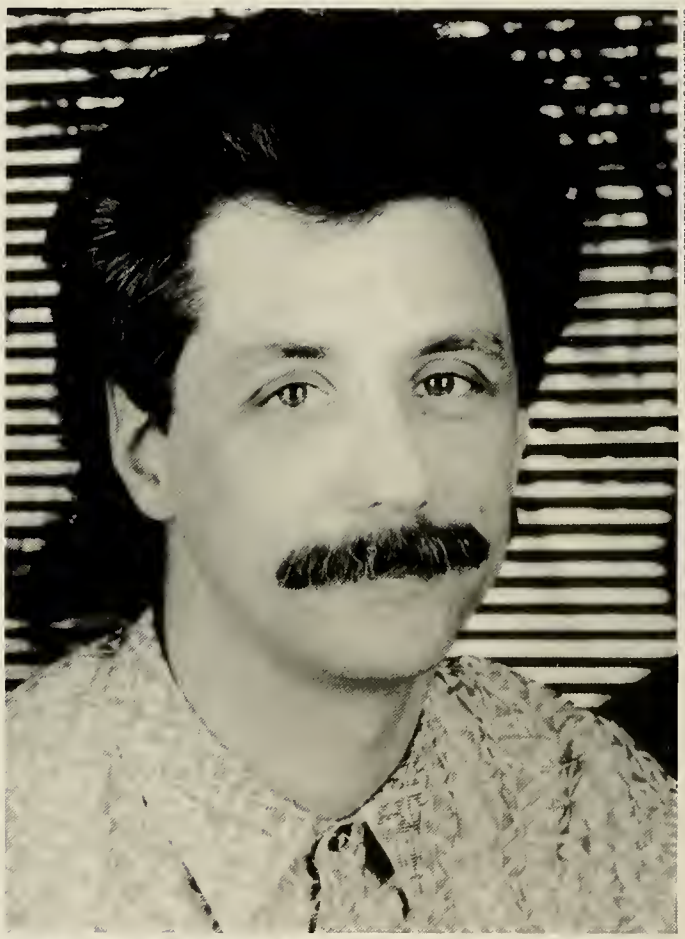
While a student, Heinen worked part time as a system programmer for New England Telephone Co., an experience that helped him land a job after graduation as a programmer in Digital Equipment's quality assurance division. He says the Plan prepared him well for working at the major computer manufacturer.

"Digital was especially team-oriented in those days," he says. "My project experience helped me to fit in quickly and to get off and running right away. It was as if I arrived an already experienced engineer. That project experience lives with me today in my whole outlook about engineering."

One of Heinen's early projects was contributing to the initial release of RSX-11M, one of the operating systems for the highly successful PDP-11, a member of Digital's original family of minicomputers. Operating systems are the programs that tell a computer how to do basic functions, like write data to files, compile and run application programs, and operate peripheral devices. "RSX-11M was the primary operating system for the PDP-11 from 1975 to 1980," Heinen says. "It was what made Digital great in those days."

Up until the early 1970s, Digital's minicomputers stood alone—there was no way to easily move data back and forth between them or to get them to work together. Heinen's next project was called DECnet, an early attempt to create a networked computer system. "Our goal was to get two PDP-11s to talk to each other over a wire; this was a non-trivial job," Heinen says. "But that architecture has stood the test of time. A lot of what we designed and built in those years helped make Digital's reputation as a networking company."

When Digital decided to introduce the VAX, a 32-bit computer designed to overcome many of the limitations of the 16-bit PDP-11 architecture, Heinen, who had developed a reputation as a prolific software writer, was asked to join a small team assigned to develop the VAX operating system, VAX/VMS. Developing this complicated software package proved a major challenge, though convincing Digital that it was needed would prove equally taxing.



PETER STEMBER/COURTESY OF APPLE COMPUTER INC.

Roger Heinen has been a pioneer in software development since his early days as a programmer at Digital Equipment Corp. nearly 20 years ago.

"The VAX was ahead of its time—ahead of its real market need," Heinen says. "In 1975, when the project got off the ground, few at Digital thought they would ever sell one. It took the sheer willpower of the management, especially Gordon Bell, to propel the project to completion." First introduced in 1978, the VAX and VAX/VMS proved wildly successful and remain the heart of Digital Equipment Corp.'s business today.

After the VMS project, Heinen decided he had had enough of operating systems and went looking for a new challenge. He found it in compilers, software that translates a program written in a high-level computer language into instructions a computer can actually execute. In 1977 he joined a four-person team that wrote a compiler for PL/1, a language widely used in scientific and business applications.

The team took a novel approach to the design of the compiler, which they later explained in a book on compiler engineering. They created a "front end" that interacted with the programming language and a "back end" that generated the machine language. While the front end would work only with PL/1, the back end was designed to be language independent, which meant it could be used in virtually identical form in compilers built to translate other higher-level languages. In fact, the team used the PL/1 back end to write a compiler for the language C.

"While no one had ever constructed a commercial compiler the way we did, now they are all done that way," Heinen says. "There were a few early pioneers before us, but I think we really made that way of building compilers a commercial success."

In the early 1980s, Digital introduced the MicroVAX, a minicomputer that uses the VAX architecture. Heinen helped develop an operating system for the MicroVAX called VAX/ELN, the first commercial object-oriented operating system (see page 24 for a description of object-oriented programming).

ELN was a pioneer in the field of distributed operating systems, which meant that it could oversee the operation of programs that ran in several pieces on multiple computers. "We were forced to push the edge of the technology in terms of how we could develop and debug programs that might be running on multiple machines," says Heinen, who won a patent for his work on the design of the distributed debugger.

During the remainder of the 1980s, Heinen became a corporate consulting engineer, a title reserved for a select group of senior engineers at Digital, and was eventually named to head the company's DECWEST Engineering Group in Seattle, which was working on new MicroVAX developments.

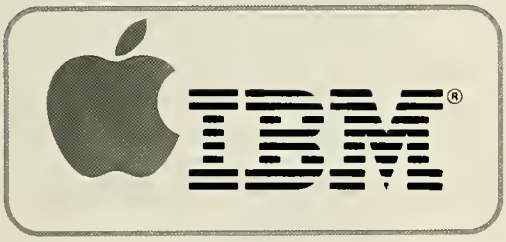
In 1990 he decided to leave Digital to join Apple Computer and the fast-paced world of personal computers. As head of the Macintosh software division, he oversees a 1,000-person operation responsible for Macintosh system software, such as the *System 7.0* operating system released a year ago, and tools for Macintosh software developers. The division also provides support, including technical advice, documentation and marketing assistance, to the hundreds of third-party companies that write application packages for the Macintosh.

Heinen says *System 7.0* and its associated software (including a new multimedia architecture) will be the heart of Apple Computer's strategy for competing against industry rival Microsoft, which markets the *Windows* operating system for IBM-compatible computers. Like the Macintosh system software, *Windows* is a graphical user interface in which users manipulate pictures and icons instead of typing in instructions.

So far, Heinen says, Macintosh is more than holding its own. "Over the past two years we've seen a tremendous increase in the overall market share for Macintosh vs. Windows and PCs. We've also had a tremendous series of hit software products—we actually think in terms of hit products; it's a very funny computer business."

While Apple's battle with Microsoft represents a competition for users who might otherwise choose IBM-based machines over the Macintosh, the company is also cooperating with Big Blue on another front. In an historic agreement announced last year, IBM and Apple will share technology and work jointly to develop a new generation of software products that will run on either company's machines, forming a bridge between the two largest sectors of the personal computer market.

A precursor to the Apple-IBM alliance was a software package called *Pink*. Developed in part by Heinen's division, the package allowed IBM programs to run on the Mac. *The Pink* development effort has evolved into Taligent, a company supported by Apple and IBM. Another jointly sponsored company, Kaleida, will develop innovative multimedia applications. "That part of the agreement is really focused on the future," Heinen says. "The object-oriented software Taligent is developing will solve problems we can foresee out into the late 1990s."



Heinen's division at Apple Computer helped lay the groundwork for an historic alliance with IBM.

Heinen says the Taligent work will address a growing problem with programmer productivity. While object-oriented programming has greatly simplified the process of writing complicated programs, it is still an inefficient and time-consuming process. "Taligent is an attempt to leapfrog evolution and make a quantum improvement in programmer productivity, something substantially farther than we can go on an evolutionary path with today's technology."

While Taligent pushes the software envelope, Heinen says his Macintosh software division is trying to improve the graphical interface that has been the Macintosh's trademark since it was introduced in the early 1980s. "Graphics interfaces were a big step back then," he says. "Now we're trying to take them to the next plateau by using more senses than just sight. For example, we've demonstrated our voice recognition software because we really believe voice recognition, if done properly, can add tremendous value to the experience of using a personal computer."

In his role as manager, Heinen says he no longer gets to do much of the active programming that makes advances like these possible. Still, he says he doesn't miss the hands-on involvement of his former life. "I'm always looking for a challenge, and right now my challenge in leading this organization is bigger that the challenge of writing some particular piece of software. But who knows, that might change someday."

Helping Out When God's Materials Fail

Each year about 240,000 Americans have surgery to replace their diseased or damaged hips and knees with artificial prostheses. The implantation of these mechanical devices, a type of operation first performed just three decades ago, has become a highly successful treatment for severe cases of osteoarthritis and rheumatoid arthritis, dramatically reducing the pain these and other debilitating joint disorders can cause and restoring to recipients a near-normal range of motion and activity.

For the past decade, Joint Medical Products in Stamford, Conn., has been a leading innovator in the design and development of knee and hip replacements. Since 1984, when the company sold its first hip prosthesis, more than 40,000 of the devices have been placed in patients. For Joint Medical Products co-founder Douglas G. Noiles '44, who today serves the company as executive vice president of engineering and development, the long and productive road to his current career in medical implants has earned him more than 60 patents.

Noiles left WPI after his sophomore year to serve in the U.S. Marine Corps during World War II. He returned to complete his degree in mechanical engineering in 1947. After graduation, he taught for three years in WPI's Mechanical Engineering Department before working as an engineer for Economic Machine Co. in Worcester, a maker of intricate machines that automatically affix labels to bottles, and for Saco-Lowell Shops in Biddeford, Maine, an old-line manufacturer of textile machinery.

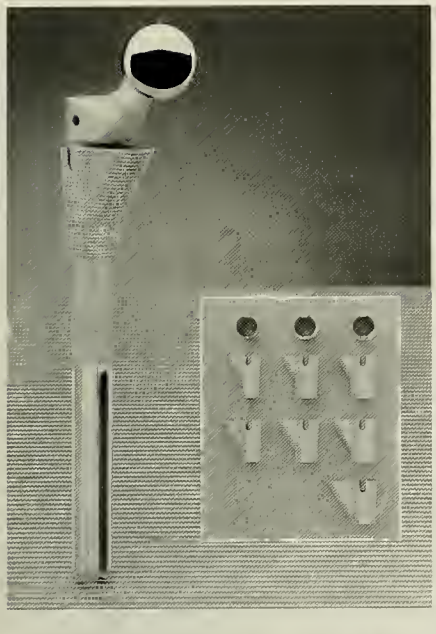
MICHAEL DORSEY

Above, Douglas Noiles with some of his designs: foreground, right, a stapler that rejoins the ends of the colon or intestines; to the right, various designs for knee prostheses; in and near his hands, parts of a knee prosthesis. Opposite, the stem of the Joint Medical Products knee replacement and, in the box, some of the tapered porous-metal-coated femoral inserts.

In 1955 Noiles joined a new Westinghouse division making tubes for radio and television. While there he was responsible for an innovation that greatly extended the life of television picture tubes. The change, a loop in a wire that had been subject to mechanical failure from frequent cycles of expansion and contraction, enabled Westinghouse to extend its warranty from three months to two years.

Noiles then joined Automation Engineering Laboratories Inc. in Stamford, Conn., a maker of specialized equipment to automate industrial processes, and became involved in a major project to develop automation techniques for the garment industry. After a colleague left to work for a new firm in Norwalk, Conn., called United States Surgical Corp., Noiles decided to join that company as vice president of engineering. At the time, U.S. Surgical was in the midst of marketing one of the first commercial surgical staplers.

The surgical stapler was invented in 1908 in Hungary, but the machines proved too bulky and too difficult to load to find widespread acceptance by surgeons for many decades. In the late 1940s Russian surgeons, fresh from the horrors of World War II, stepped up the development of the devices, which enable wounds to be closed and internal organs to be reconstructed much more quickly



COURTESY OF JOINT MEDICAL PRODUCTS

than with conventional sutures.

One of U.S. Surgical's first staplers, used to close the skin at the end of an operation, consisted of a disposable cartridge that contained the staples and the staple-forming mechanism, and a hand-held instrument that powered the cartridge. The cartridge was not reliable and the instrument, powered by compressed carbon dioxide, was fraught with problems, made worse when it was steam sterilized.

Noiles helped solve the problem with the cartridge and developed a hand-powered instrument that proved more reliable than the gas-powered model. He also developed a ligator, an instrument that could quickly tie off a blood vessel in two places and cut in between, and contributed to the development of a device that can draw together the ends of the intestine or colon after a section has been removed and join them instantly with up to 33 staples. Work on these and other technologies earned Noiles the Eli Whitney Award from the Connecticut Patent Law Association in 1985. The award is given annually to an individual who has made significant contributions to law or science.

To help get surgeons interested in its stapling products, U.S. Surgical decided to offer orthopaedic devices. The hope was, Noiles says, that surgeons would try the implants and, at the same time, discover the advantages of using staples in this and other kinds of surgery. "An opportunity presented itself in 1971," he says. "American surgeons wanted to do hip surgery, but the acrylic plastic bone cement developed in Europe for this type of procedure had not yet been approved by the FDA."

Russian surgeons had developed a hip prosthesis that required no cement, and U.S. Surgical obtained the rights to it. The hip consisted of two titanium parts that replaced the ball and socket joint of the hip. A long, tapered stem topped with a cobalt chromium ball was driven into the top of the femur, while a cup-shaped socket was inserted into the pelvis. U.S. Surgical added flutes to the stem to enable it to resist rotation and replaced the metal the Russians used inside the pelvic cup with ultra-high-molecular-weight polyethylene.

The company also decided to develop its own knee replacement. The knee, a hinge that attached to the femur and tibia, replacing the function of the patient's own knee, would be a "last resort" prosthesis, to be used in about 5 percent of knee replacements where the body's own muscles and ligaments are not capable of holding the parts of the knee joint together properly or where a prior artificial knee joint has failed.

At the suggestion of surgeons, who noted that the normal tibia is capable of limited rotation, Noiles designed a shaft and bearing that enabled the tibia to rotate. He added stops that limited the rotation of the tibia to 10 degrees to either side of center. When tests showed the design worked well, Noiles increased the range of rotation to 23 degrees. "This turned out to be a relatively successful device," he says. "We got a patent on it and have licensed several companies to use the invention."

In 1972 the FDA approved the use of acrylic bone cement, and interest in the U.S. Surgical hip joint diminished. In addition, by the end of the decade the company's staplers were becoming great successes, and its orthopaedic products became less important. Noiles tried unsuccessfully to sell the hip and knee designs to other companies.

By this time the character of U.S. Surgical, which had grown from a small company to a major corporation earning more than $100 million, had changed. "I didn't seem to fit in as well as I had when the company was smaller," Noiles says. "So I left U.S. Surgical and continued to try to sell the technology. I finally decided somebody had to do something with these devices."

With C. Anthony Whittingham, former vice president for finance at U.S. Surgical, Noiles founded Joint Medical Products in 1982. Noiles' first task was to reexamine and improve upon the Russian hip replacement. Unlike most hip prosthesis then on the market, the Russian hip was constrained, which meant the ball was enclosed by the socket and the two pieces could not be separated. The design made the hip difficult to install and reduced the patient's range of motion; however, it did prevent dislocation, an occasional problem in hip replacements.

Noiles created a new socket that would hold the joint parts together after the surgeon had implanted them separately and joined them. Noiles also designed the socket so it could be screwed into the naturally spherical depression in the pelvis. This threaded socket was eventually replaced with a socket coated with a porous metal. After implantation, bone would grow into the cavities in the coating, forming a strong bond that held the cup in place.

Noiles also invented an insert for the socket that could be adjusted into a wide range of positions and then locked in place. This enabled the surgeon to fine-tune the angle at which the femoral component met the socket. This patented design has been copied by other manufacturers, but Noiles says Joint Medical Products is involved in a patent interference proceeding to determine the technology's rightful inventor.

To make the hip more versatile, Noiles created an extensive series of tapered inserts that fit into the femur and into which the stem of the femoral component fits. The porous-metal-coated sleeves enable the surgeon to custom fit the implant to the interior of the bone and help distribute the patient's weight evenly over the bone. Noiles also created a range of sizes for the ball, the femoral stem and the pelvic socket cup.

Studies have shown that the Joint Medical Products design is more stable that other designs, Noiles says. "It's also pretty much accepted as the prosthesis of choice for revision surgery—when a hip prosthesis must be replaced—because the range of sleeve sizes we offer enables the surgeon to work with the great range of cavities that can result when an old prosthesis is removed."

Currently, Joint Medical Products is preparing to introduce an improved version of the knee joint Noiles developed for U.S. Surgical. It also continues to monitor the performance of its hip joints and to make design changes as new information and ideas come to light. "Nobody has the answer to how to build a perfect joint replacement," Noiles says, "because we don't have God's materials. The field is always evolving, changing rapidly, which is testimony to the fact that we haven't found the right answer yet. But that also makes this an exciting business."

Probing the Mysteries of The "Demon Stars"

In ancient times, watchers of the evening sky observed a mysterious star that would glow brightly for three nights and then inexplicably dim before brightening again and starting the cycle anew. The Arabs called it "Al ghoul" or the demon star. Today, scientists know that Algol is actually two stars, a small but bright dwarf and a much larger companion that regularly eclipses it.

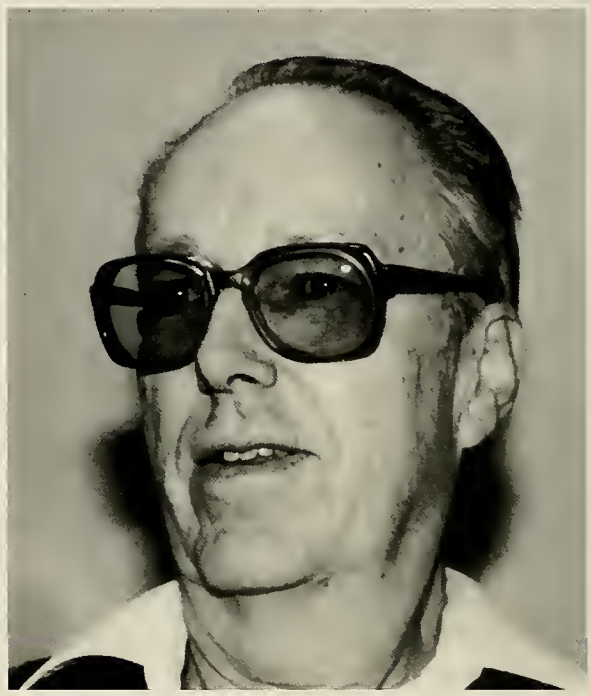
Since those days, astronomers have discovered that binary star systems like Algol occur commonly throughout the universe. Within the past few decades, they have also come to realize that these systems hold clues to fundamental physical processes that may help explain a wide range of cosmological phenomena.

For nearly 30 years, Edward C. Olson '52, professor of astronomy at the University of Illinois at Urbana-Champaign, has been studying a class of double stars called close or interacting binaries. The stars in these systems orbit one another in close proximity and have orbital periods ranging from a few days to a few weeks.

What makes interacting binaries especially interesting, Olson says, is the tendency of matter to flow from one star to the other, where it forms a broad disk of gaseous material that slowly spirals inward until it is deposited or accreted onto the surface of the recipient star. These accretion disks resemble similar structures associated with a number of other stellar objects.

"Accretion disks are integral elements in the formation of stars and planets," Olson says. "There are accretion disks associated with binary star systems that produce regular thermonuclear explosions—so-called novae. And there are probably accretion disks around quasars and the black holes thought to be at the center of very active galaxies. The accretion disks we see in relation to interacting binaries are weak, low-density examples, but they are highly observable, which is why we go after them."

Accretion disks are a normal stage in the evolution of most close binary systems. Like all stars, the companions that make up a binary coalesced from clouds of interstellar gas. Eventually, as gravity accelerated the collapsing gas balls, rising temperatures and pressures reached a point where hydrogen atoms began to fuse to form helium. The energy from this thermonuclear reaction stabilized the collapsing bodies, which settled into life as small, hot stars called dwarfs (our own sun will remain in this stage of evolution for another four billion years).

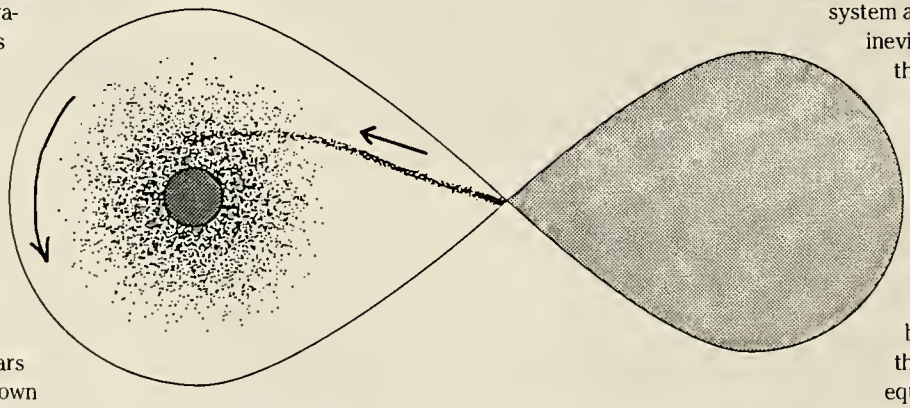


Edward Olson has spent nearly 30 years studying close binary star systems, which may help explain such celestial phenomena as black holes, quasars and the formation of stars and planets.

Eventually, a dwarf star will consume all of the hydrogen in its core. As the atomic furnace cools, the energy that has kept gravity at bay subsides and the star begins a brief period of collapse. At some point, though, gravitational pressure ignites a thin shell of hydrogen around the collapsing core, causing the star's outer envelope to expand into a giant reddish ball.

Because the masses of the partners in a close binary system are rarely identical, one star inevitably uses up its fuel before the other. As the spent star becomes a red giant, the gravitational force of its companion distorts its expanding gas envelope into a teardrop shape.

Eventually, the peak of this teardrop (called the Roche lobe) passes the point between the two stars where their gravitational effects are in equilibrium. Like water reaching the top of a dam and overflowing, gas streams from the giant star to the dwarf at hypersonic speeds. If



In interacting binaries, gaseous matter flows from a giant star, right, to a dwarf, forming an accretion disk.

the stars are close enough, the gas stream may strike the surface of the smaller star directly. But more often, it passes behind and wraps around the star to form the characteristic accretion disk.

Because of their proximity, close binaries appear as single points even in the most powerful optical telescopes. Therefore, scientists like Olson must use creative techniques to pick apart the light arriving from a binary to "see" the physical processes occurring on each of the stars and in the accretion disk.

Olson, working in collaboration with Paul Etzel, an astronomer at San Diego State University in California, has been observing binaries for many years through a one-meter reflecting telescope at the Mount Laguna Observatory, operated jointly by San Diego State and the University of Illinois about 50 miles east of San Diego. The telescope is equipped with a charge-coupled device or CCD, an electronic detector that builds up a charge when it is exposed to light. After an exposure, the charge is read from the CCD in digital form. The process is faster and more sensitive than the photographic methods once used in astronomy.

The CCD can also be linked with spectrographs, which, like prisms, break the light from a binary system into its component spectra. These spectra show whether the stars or the accretion disk absorb or emit energy at specific frequencies. The combination of absorption and emission lines in the spectra indicate which elements are present in the objects and also serve as their unique signatures.

Seen through the spectrograph, an accretion disk produces a characteristic double-peaked hydrogen emission spectra. The two peaks are produced by the opposite sides of the disk—one spins toward the Earth and is therefore shifted by the Doppler effect toward the violet end of the spectrum; the other spins away from the Earth and is Doppler-shifted toward the red end. The extent of the Doppler shift indicates how fast the disk is spinning.

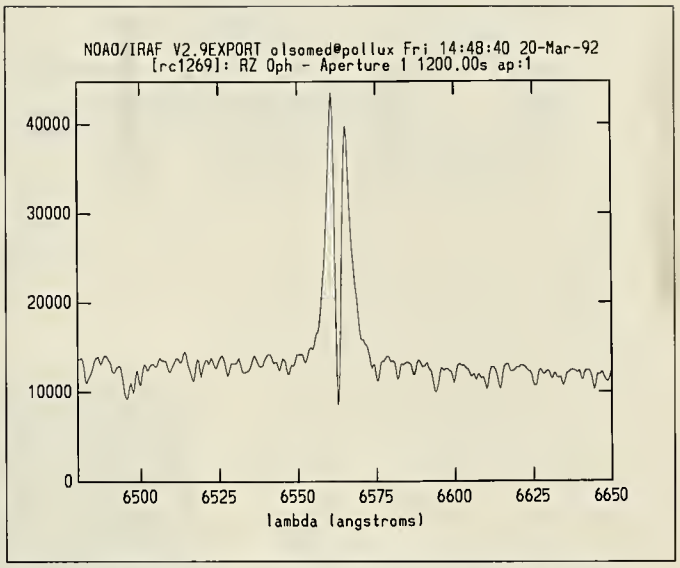
By viewing these spectra under varying conditions, Olson gleans clues about the structure and behavior of the disk. Observations like these may provide an answer to one of the great mysteries associated with accretion disks: what causes the gas to spiral in and become deposited on the star?

Scientists believe that a process called viscous damping is responsible, but to date they have not been able to fully explain how it works. The viscosity of the disk—the property that causes the gas particles to lose their angular momentum and fall toward the star—may result, in part, from collisions of gas molecules in the disk. As they collide, they give up energy as heat. Gravitational effects from the two stars and, perhaps, weak magnetic forces in the disk itself may also contribute.

"There's a lot going on and it's always a question of just how much we'll be able to understand," Olson says. "It's quite a challenging process. All you see is that little point in the telescope. The rest of it is solving puzzles."

For several years, Olson has been at work on a computer model he hopes will become a powerful tool for unraveling many of those puzzles. The base for the model, the first ever developed for this class of binary star system, is the data from the observations Olson and Etzel have made of 12 binary star systems. Olson says the model, still in development, will be used to make predictions about how the disks should behave—predictions that can then be compared to the results of actual observations.

"The model is really a diagnostic tool that probes the temperatures, pressures, rotations and viscous dissipation in the disks,"



Accretion disks produce characteristic double-peaked spectra. The peaks are caused by the edges of the spinning disk, each of which is Doppler shifted toward a different end of the spectrum.

Olson says. "We should be able to investigate many of the important mechanisms associated with accretion disks using the model and our observations. Our hope is that the model will agree with the observations, although that doesn't always guarantee that it's the right model."

Olson says his interest in astronomy was sparked at a young age. He majored in physics at WPI because it would provide the best possible foundation for a career studying the interactions of celestial objects. After graduation he taught for a year at WPI before he was drafted into the U.S. Army. He spent two years as a physics assistant studying the performance of Nike and Ajax missiles at the White Sands Proving Grounds in New Mexico, and then, in 1961, earned his Ph.D. in astronomy at Indiana University, where he studied asymmetries in solar absorption lines caused by convection and turbulence in the Sun's atmosphere.

He continued studying the solar spectrum at Smith College as a member of the faculty of the Four-College (now Five-College) Astronomy Department in Western Massachusetts. It was during those years that he first became interested in close binary systems, a subject he continued to pursue at RPI and at the University of Illinois, which he joined in 1966. "The first ideas about how these systems evolve were just being advanced," he says. "But the observed details were not very well in hand."

In the intervening years, Olson says, it has been the quest to fill in those details that has kept his work exciting. "Astronomy has always had major puzzles throughout its history," Olson says. "The situation today is not that different, in that sense. The nuts and bolts of practicing scientists is solving puzzles and understanding challenging situations."

Charting A New Course

By Michael Dorsey

In its Maplewood, N.J., offices, Hammond Inc. is using a revolutionary computer system to make maps. In the process, this 92-year-old company is taking the ancient art of cartography to places it has never been before.

PHOTOS BY MICHAEL DORSEY

Caleb Hammond '37 with just a few of the maps and atlases published by Hammond Inc.

Over the course of his 55-year career, Caleb D. Hammond '37, chairman of Hammond Inc., the nation's second largest publisher of maps and atlases, has seen the world change a great deal. Nations have come and gone, borders have shifted, cities have worn new names, rivers have been diverted, and islands have risen from the sea. But of all these transitions, the rise and fall of the Soviet Union has a special place among Hammond's memories.

In 1939, after two years as a lubrication and sales engineer with the Texas Co., the forerunner of Texaco, Hammond joined the family-owned company founded by his grandfather nearly 40 years before. He was on the job only a short time when the Soviet Union signed a nonaggression pact with Hitler's Germany and rolled into the Baltic Republics of Estonia, Latvia and Lithuania.

"At the time we were doing an atlas jointly with the Encyclopaedia Britannica," Hammond remembers. "We decided we were going to show these republics as part of Russian territory. The U.S. government saw the atlas and said we should show them as independent republics, since the U.S. had not recognized the occupation. They wanted us to call the atlases back, but they finally decided there was nothing they could do about it."

Fast-forward 54 years. On the heels of an unsuccessful coup, the U.S.S.R. is literally falling apart and those same three Baltic republics have earned their independence

once again. This time the winds of change are less kind to Hammond Inc. Sitting in a warehouse are thousands of copies of the latest edition of Hammond's *Citation World Atlas*, which includes maps of a complete Soviet Union.

"Fortunately, many of those copies were unbound," Hammond says. "We are currently reprinting the first 72 pages, which include maps of the U.S.S.R. and the countries that border it. This Russian thing has been a pain in the neck, but it's changes like this that keep us in business. This year the Russians just overdid it."

Change has been a fact of life for Hammond Inc. since its founding in 1900. The story goes that Caleb Stillson Hammond, a sales manager for Rand McNally & Co., asked for a $5-a-week raise from his employer. When he was turned down, he decided to quit and set up his own mapmaking business.

One of Hammond's first products was a wall map with the United States on one side and the world on the reverse. The world map was drawn with a revolutionary new projection that showed countries in the northern latitudes more accurately than conventional maps. A world atlas soon followed and in succeeding years Hammond stayed on top of social trends and world news, publishing special maps and collections tied to such events as the San Francisco fire, Commodore Perry's trek to the North Pole, and World Wars I and II.

The company survived lean times in the 1930s and arrived at its golden anniversary in 1950 a thriving enterprise. That year corporate offices were moved from Manhattan, where Hammond had established the nation's first map store in 1911, to the New Jersey site the company has occupied ever since. Today Hammond continues to serve many of the markets it has developed during its first 92 years.

For example, it produces the maps included in encyclopedias published by such companies as Encyclopaedia Britannica, World Book, Funk and Wagnalls, and Groliers. It publishes an extensive series of maps and atlases for use in schools. Its maps and reference and travel atlases find large markets in bookstores and map and travel shops. And the company produces a wide variety of items used as promotions and incentives by companies and organizations ranging from Time Inc. and *Reader's Digest* to Ciba Geigy.

Through all this change, Hammond Inc. has remained a family business, though that almost changed a few years back. Caleb Hammond became president of the company in 1948, upon the death of his father and uncle, and chairman in 1968. At the age of 62 he retired to accept the post of chairman of the board of the Maplewood Bank and Trust Co. At the time, his brother, Stuart, was president of Hammond Inc., his son, Caleb Dean Hammond III, was executive vice president, and his daughter-in-law, Kathleen Hammond, a former advertising executive with the *New York Times*, was vice president in charge of marketing.

For some time, Stuart Hammond and several other relatives had been entertaining offers from potential buyers. When a cousin decided to place her sizeable share in the company on the auction block, Caleb Hammond and his son and daughter-in-law decided the time had come to act. They pooled their resources and bought the relative's holdings, along with several smaller shares, gaining a controlling interest in the firm. In the aftermath, Hammond rejoined the firm as chairman; his son, Dean, became president; and Kathleen Hammond was named executive vice president.

What they found themselves in control of, Hammond says, was a company that had been languishing for several years as relatives debated its future direction. To revitalize Hammond Inc., the company's new executives settled on a radical plan that would not only change the face of this 85-year-old firm, but the state of the art of cartography itself.

While the technology of mapmaking had evolved considerably from the days when craftsmen laboriously drew each map by hand, it was still a time-consuming and largely manual process. Artists and draftsmen, working at drawing boards, handcrafted maps with the help of editors, who drew on the latest information carefully stored in banks of file cabinets to assure the accuracy of names, river courses, mountain elevations and so on.

The finished drawings were photographed and turned first into negatives and then into plates for the printing press. Updating maps meant retrieving old drawings from storage, pulling off old, incorrect labels, redrawing outdated features, and redoing indexes—a process that could easily consume several months. Hammond's new management team looked at the significant inroads computers were making into other areas of business—including the printing and publishing industries—and wondered why their business, too, could not benefit from the computer revolution.

The company began to build what it now calls the Hammond Digital Cartographic Database (HDCD), a comprehensive file of information about the entire world that enables Hammond Inc. to generate maps of virtually any area at scales as small as 1:500,000. The first step in creating HDCD was to acquire a public-domain database created by the U.S. government. The company also purchased about $5 million in computer equipment, including specialized graphics terminals designed for cartographic work and made by Intergraph Corp. in Huntsville, Ala.

While a useful starting point, the government database was less than perfect, Hammond says. "We discovered that it had many, many inaccuracies. Also, we found out early on that there were a lot of things we wanted to do that the government never

Caleb Hammond watches as his company's chief draftsman, Herbert Pierce, touches up the negatives for a new map of the world.

worried about. For example, we had to spend a lot of time making sure that one section of the world would line up accurately with the sections around it."

To create the software that would make this and other vital tasks possible, Hammond hired several computer programmers and called on a number of computer experts. Most notable among these was Mitchell J. Feigenbaum, professor of mathematics and physics at Rockefeller University in New York. Kathleen Hammond had met Feigenbaum at Cornell University in 1970, when she was an undergraduate and he was completing postdoctoral work.

After two years at Cornell, Feigenbaum completed another two years of postdoctoral studies at Virginia Polytechnic Institute and then joined the staff of Los Alamos National Laboratory in New Mexico, where in 1976 he discovered universality, a theory that explains what happens as natural systems, such as flowing water, clouds or rising smoke, make the transition from orderly to turbulent or chaotic behavior. The discovery was a critical step on the road to chaos theory, widely considered one of the most important scientific advances of modern times.

Using the techniques of object-oriented programming (see story, page 24), Feigenbaum developed the algorithms that knit the information in the database into a seamless representation of the globe (one that would cover two-thirds of a football field if printed out at the nominal scale of 1:3,000,000). He also developed techniques that enabled the computer to adjust the level of detail displayed depending upon the scale of the map.

For example, the complicated coastline of Maine can be shown in far greater detail on a map that displays just the state itself than on a map of the whole Eastern Seaboard. The software Feigenbaum developed also enables the computer to choose a projection for each map that displays that region of the world in the most realistic and accurate manner.

Another key piece of software, on which a patent is currently pending, places type—such the names of cities and towns—on the map, a task that can be challenging in heavily developed areas where population centers lie close together. "Initially, we would have crashes in these areas where the names would just run into each other," Hammond says. "Feigenbaum developed a way of handling this by relocating names in an orderly way if they start to crash. This is something the government has been trying to do for 25 years."

To date, the development of the database has consumed five chronological years and 150 man-years of effort. There are two types of data in the database. Linework includes more than 1,000 types of geographic features, including coastlines, rivers, mountains, islands, roads, canals, railroads and political boundaries. Some details can have complex codes that include information that may show up only at certain map scales. For example, a detailed map might show the exact width of a river along with the courses of all of its tributaries, while a map with a broader scale may simply show the path of the main branch.

Textual information is stored separately within the same database. Each population center is coded with its local name, its standard name as determined by the U.S. Board of Geographical Names, and its historic name or names. The company is also translating these names into multiple languages for maps and atlases published internationally. In addition to its name or names, each city and town is coded with its population. The population data determines how large the locality's name will appear on a map and—depending upon the map's scale—

whether it will appear at all.

There are no actual maps in the system. Working at computer terminals, a cartographer creates a map by retrieving from the database information about an area bound by designated coordinates. The computer automatically draws in the appropriate borders and map scales. The cartographer can choose from a wide range of colors and patterns to indicate geographic features, can use any of dozens of symbols for points of interest, and can select appropriate fonts for the type.

Finished maps can be output in a number of ways. For proofing, they can be printed on color computer terminals or on a host of high-resolution plotters and printers. Information can be stored on magnetic tapes or disks. And maps ready for publication can be sent to a device that generates four-color negatives for printing.

While the creation of the database was largely the work of computer experts, its maintenance will fall to Hammond's staff of editors. "The world is constantly changing," Hammond says. "Everybody hears about changes like Leningrad becoming St. Petersburg once again, so you have to get those right. But there are so many other changes that happen all the time that few people hear about. The nice thing about this database is that you only have to make a change once. Whether it's a name change or a change in the course of a river, once it's in the database that change will be made for every map we produce with the computer."

So far, Hammond has produced just a few products electronically, most notably a 1:4,000,000-scale map of the Indian subcontinent created last year for an international book fair. In addition, a computerized collection of world flags was recently used in the production of wall maps of the United States and the world (the maps themselves were produced conventionally).

Currently in production is the new *Hammond Atlas of the World*, a 304-page, 11-by-14-inch volume that will go on sale in September—by far the most detailed and accurate atlas the company has ever produced, Hammond says. All of the more than 200 maps in the collection are being created with the HDCD. When the atlas is complete, the database will be employed to produce a wide range of other products, including many more area maps for travelers, small pocket-sized atlases, school atlases and—should a comprehensive road network be added to the database—a series of road maps.

Opposite, cartographers update a computer-generated map of the Indian subcontinent. Above, Caleb Hammond looks over one of the thousands of maps in the Hammond Inc. archives.

Caleb Hammond, who is a member of the American and Royal Geographical societies, a former director of the Association of American Publishers (then known as the American Textbook Publishers Institute), and a trustee emeritus of WPI (from which he recently received the Robert H. Goddard '08 Award for Professional Achievement), says the database will enable the company to easily produce specialty maps of all sizes, in a variety of custom styles, and with an infinite variety of information tailored for individual customers. A good example, he says, are the encyclopedia publishers with which Hammond has worked for decades.

"In the past we've been able to give these companies maps at whatever size they wanted, but they all received basically the same maps," he says. "They've always wanted their maps to look different than anyone else's. Now it will be possible for us to do that. We'll be able to give them their own selection of areas and color treatments. They can choose to show mountains or not, and so on. We think this will open up brand new areas for us."

With the computer it will be possible to produce all of these products in a fraction of the time that was once necessary. For example, creating the map of the Indian subcontinent from scratch, a task that might once have consumed six months of time for a team of editors and designers, took only a few weeks. Twice that much time would have been required to assemble the map's index of town names (something the computer now does automatically in seconds) in the "old days." Hammond says that in time, as the company gains experience with its computer system, the process should become even faster.

While Hammond will create nearly all of its future maps and atlases with the computerized database, Caleb Hammond says there will always be products that can better be created or updated in a more traditional manner. These include special topical maps in various school atlases on things like infant mortality and the location of fossil deposits. In addition, he says, the company has thousands of maps in its archives, some of which will continue to be updated from time to time and reused. Work like this will keep the company's staff of draftsmen, some of whom have been with the company for decades, busy for years to come.

Currently, Hammond Inc. has the field of commercial computerized cartography virtually to itself. No other major mapmaker has created the type of advanced cartographic tools that Hammond has pioneered over the past five years. "I've enjoyed watching this progress," says Hammond, who adds that he may retire once again when the new atlas finds its way to bookstores this fall.

"This is going to be the future of our company, and I couldn't be happier. In truth, I had no business buying out that relative, but I could see sections of the company withering and dying on the vine. I said, 'Damn it, we're going to stick with it and turn this company around.' That's what we're trying to do."

Building a New Window on the World

By Michael Dorsey

A NEW APPROACH TO DESIGNING LARGE SCIENTIFIC DATABASES PROMISES TO GIVE GLOBAL CHANGE RESEARCHERS A POWERFUL NEW TOOL FOR UNDERSTANDING OUR PLACE ON THE PLANET.

In an office of the not-too-distant future, a climatologist sits down at her computer workstation and types in a simple question: Has the rainfall across Southern California been affected by the shrinking rain forests of Brazil? In a few moments, the screen is filled with a patchwork of images, icons and menus.

Using the computer's mouse to link together certain pictures and icons, then typing simple answers to questions the computer poses, she sharpens her search and then goes beyond her initial query, drawing in data on wind patterns, atmospheric gas exchange and solar radiation—some of it gleaned from computers located thousands of miles away—and integrating it with information coded in weather satellite photos pulled from a data bank in Washington, D.C. Finally, she displays the results of her new computer model as a time-sequenced series of high-resolution maps.

It may sound like science fiction, but a system like this is the ultimate goal of a new project being undertaken by a research team consisting of three faculty members in WPI's Computer Science Department and a professor of geography at Clark University. With a two-year, $315,000 grant from the National Science Foundation, the team hopes to take the first steps toward a radical new way of handling the huge amounts of information that confront scientists studying the phenomenon of global change.

WPI was one of 11 colleges and universities around the nation (out of 115 that submitted proposals) to receive funding in the first round of a new NSF initiative aimed at finding innovative ways to manage large scientific databases. The goal of the program is to overcome the limitations of the database software commonly used in scientific research, most of which is modeled after packages designed for business applications.

For the most part, current scientific databases can't easily handle the staggering quantity of data often gathered in geographic or climatological research (weather satellites, for example, collect billions of bits of data every day). In addition, business-oriented databases generally lack the flexibility to adapt easily to new types of data or to new ways of analyzing it. This quality—called extensibility—is also required to accommodate metadata, or data about the data, which can include information about how, when and where the data were created, and about how they have been processed or recalibrated in the meantime.

"As we looked at existing software," notes Nabil I. Hachem, assistant professor of computer science, "we also found that most

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Graduate students Yu-Hong Zhang, left, and Ke Qiu are developing parts of a new database program that may revolutionize the way geographic and cartographic information is stored and analyzed.

concentrates either on the management of data or on the analysis of data. We wanted to find a way to integrate these functions."

Hachem says the researchers also noted that most existing database systems designed for geographic and cartographic research—so-called geographical information systems or GISs—deal adequately with either spatial data (data that describes the distribution of things in space) or temporal data (which describes how something changes over time). A goal of the global change database project is finding a way to integrate spatial and temporal data, making it easier for researchers to study how global systems change over time, and to model how they may change in the future.

To meet these challenges, the research team, which also includes Assistant Professor Michael A. Gennert and Associate Professor Matthew O. Ward of WPI's Computer Science Department and Clark University Professor J. Ronald Eastman, is turning to a technique called object-oriented programming.

A traditional program is a long list of instructions—called code—that tells a computer how to find and analyze data and what to do with the results. Sometimes hundreds of thousands of lines long, such programs can become so unwieldy that they are virtually impossible to update or even understand.

Object-oriented programs consist of discrete, self-contained modules called objects. Most objects describe specific entities, for example a thunderstorm over Kansas or the annual snowfall on Mt. Kilimanjaro. Encoded within the object is a description of how it behaves. For example, the snowfall object might include daily totals for snowfall and the program for computing a yearly average. Metadata about the object can also be bundled into the object itself.

With object-oriented techniques, computer programs no longer need be handcrafted, as most are now. They can be assembled from existing objects, much like computers themselves can be pieced together from off-the-shelf components. In addition, objects are easily extensible—they can even evolve into new objects with new characteristics as the demands on them change. For example, the annual snowfall object can easily become a monthly snowfall object or an annual rainfall object.

"This is one possible solution to the problems posed by large scientific databases," Gennert says. "We think it's a good solution, but we'll have to prove that. One of the reviewers who read our proposal said our idea is either brilliant or it will never work."

The idea for the global change database began about four years ago when Gennert and Ward became interested in finding ways to automate the process of creating and manipulating maps. They visited the U.S. Geological Survey in Reston, Va., to learn about the most pressing needs in automated cartography. Then, with faculty members from the Electrical Engineering Department, they put together a proposal to the NSF and the Defense Advanced Research Projects Administration (DARPA) for funding for a knowledge-intensive map analysis program.

While the proposal was not funded, it led Gennert and Ward to do further research and develop, with the help of a graduate student and an undergraduate completing his Major Qualifying Project, a prototype map-displaying program. In the meantime, the U.S.G.S. announced its intention to begin funding research on global change—a broad area that encompasses the complex relationships among the Earth's physical and biological systems and how they are affected by the activities of man. The causes and consequences of global warming, the destruction of the Earth's ozone layer, and the deforestation of the tropics are all subjects that fall within the realm of global change.

With the U.S.G.S. announcement as an incentive, Ward and Gennert drafted a white paper in which they refined their ideas and proposed a new software architecture that appeared to solve the needs of global change research. "This system would be able to store and manipulate data in a more general and powerful way than what the U.S.G.S. had envisioned," Gennert says. "We thought it was the right kind of forward-looking system, one that the field would need eventually."

Gennert and Ward sketched out a working diagram of their system on a blackboard in Gennert's office and modified it on a regular basis. As the system developed, the two researchers realized they were straying further and further from their own areas of expertise, which include image processing, image understanding, artificial intelligence and visualization. "We realized that this is really a large database problem," Ward says. "The ranges of types of data and the sizes of the

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Left to right, Professors Michael Gennert, Matthew Ward and Nabil Hachem.

databases posed problems that went beyond our abilities."

They enlisted Hachem, whose area of interest is very large data and knowledge bases. Shortly after Hachem joined the group, the NSF put out a request for proposals for new approaches to designing scientific databases. "They wanted a system that was appropriate for a specific field of current importance, but which incorporated ideas that could be extrapolated into scientific databases in general," Hachem says.

Knowing that scientific databases often fall short because database designers focus on technology instead of the needs of the people who will use that technology, the team forged a link with the George Perkins Marsh Institute in the school of geography at Clark University. "We felt that being part of an interdisciplinary team would help us understand the needs of global change researchers," Hachem says.

Those needs are considerable, as Hachem, Gennert and Ward have discovered. Scientists in this field deal with a wide range of data types, including cartographic data, such as elevations and information about land use and water runoff; satellite images of vegetation and weather patterns; point data on rainfall and solar radiation; and the output of mathematical models of groundwater flow and atmospheric circulation.

"We've had weeks of discussions just to define what data is," Ward says, "and to convince ourselves that our system can cover a significant portion of the various types of data that global change researchers use. We don't want to leave out anything that's going to prevent our system from being useful."

The diversity of data is only one of the challenges the researchers will face as they develop the global change database. Further complicating their work is the fact that the data are recorded in a wide variety of ways. Notes Ward, "Everything has a different file format. And it's all recorded at different resolutions, different scales, and with different accuracies. How do you compare apples and oranges? You can either mold one type of data into another, or find some middle ground and hope you haven't lost too much of the data in the conversion."

With object-oriented programming, each data object can contain a description of the characteristics of the data it contains. Other objects can be programmed with rules for how different types of data can be manipulated in a sensible way. "For example," notes Gennert, "it makes sense to ask for annual rainfall by summing the rainfall totals for each month. On the other hand, it doesn't make sense to get population growth by totaling the population totals for each month. You have to know how the data can be properly interpreted, interpolated, extrapolated, predicted and calibrated."

"Our goal," Ward says, "is not to solve all these problems, but to create an environment in which they can be solved. Extensibility is a requirement for doing that. As people come up with new needs, new abilities and new data, the system will have to grow with it."

By making each type of data a separate object, the researchers hope to make the system easy to modify. Adding new data types or new analyses, for example, should be as easy as plugging new objects into the database or modifying existing objects.

Another important goal of the global change database project is making the program as easy to use as possible. To do that, they will place a visual interface—a sort of interpreter—between the user and the software. Ph.D. candidate Yu-Hong Zhang is currently developing a system that will enable users to ask questions about natural phenomena that change in both space and time—such as a moving cold front or the changing boundary between climatological zones—by manipulating images instead of typing long queries in an arcane computer language.

"With most databases, forgetting one component of the query can result in a long, senseless search," Ward says. "We want to avoid that. We also want to have reasonable default specifications so people don't have to specify 20 things before they get something out of a search. So we're creating a hybrid visual-text system that will enable users to both extend the system and get information out of it."

Another Ph.D. candidate, Ke Qiu, is at work designing the model for the data objects, and is also developing the system that will retrieve data and guide its analysis in response to a user's queries. "We don't want the user to have to go through all the steps he or she must do now—finding the data, converting it to common scales and so on. We also want the user to be able to take the whole sequence of operations the computer might perform on a certain type of data and turn that into a new object that can be used again and again."

Over the next two years, the team will develop a working prototype of the system that will then be tested with a wide range of geographic and cartographic data provided by Clark University. While the early prototypes of the new global change database software will be tested with data residing on computers at WPI and Clark, the designers would ultimately like to give their system the ability to tap into international computer networks to gather information from diverse and potentially incompatible computer systems located around the world.

PHOTOS BY JANET WOODCOCK

AL ANDERSON STARTS A NEW CHAPTER

By Bonnie Gelbwasser

After nearly three decades as the head of the Institute's innovative and extensive collections, WPI's library director is set to retire.

Here's a riddle: Which word describes some of the materials in the George C. Gordon Library *and* the man who has presided over WPI's library collections for more than a quarter century? To those who know head librarian Albert G. Anderson Jr., the answer is simple: "reserved."

"Maybe it's my Scandinavian upbringing," says Anderson, who will retire on June 30 after 29 years as the library's top administrator. Only the sixth librarian in the college's history—and the only man to have held the post—Anderson was preceded by Emily M. Haynes, who served from 1902 to 1942, and Bonnie-Blanche Schoonover, who was head librarian from 1942 to 1963.

Ask him about the hundreds of books and the primitive art that line the walls and shelves of his office on the first floor of the library and all he'll volunteer is, "The library is not my whole life. I have many other areas of interest." But ask this private man about the library and he becomes instantly loquacious.

Anderson, who was born in Fargo, N.D., earned a bachelor's degree from North Dakota State University, a master's from the University of Wyoming, and a master's in library service from the University of Illinois.

In the early 1960s he was living in Ann Arbor, Mich., and working as head of technical information for the Bendix Corp. and as a consultant for General Electric when he met Albert M. Demont '31, a WPI trustee. Demont mentioned the meeting to M. Lawrence Price, then dean of faculty at the Institute, and when Bonnie-Blanche Schoonover announced her retirement, Price invited Anderson to apply for the post. "When I

Students take in an exhibit on the Tiananman Square uprising in the third-floor gallery in Gordon Library.

saw Worcester on the map," he says, "I thought it must be pronounced 'Worchester.' Upon my arrival I was put straight."

Anderson selected a propitious time to relocate to the city. When he arrived on campus in 1963, WPI's library was actually eight separate collections in six different locations. Humanities and social science publications were housed in a one-room library in the basement of Alden Memorial; the Chemistry and Chemical Engineering departments shared shelf space in Goddard Hall; and the Physics Department and the Civil, Electrical and Mechanical Engineering departments maintained their own separate collections.

Anderson immediately became part of a team, lead by Harry P. Storke (who had assumed the presidency of the Institute the year before) that was planning a new library that would house these varied collections. "President Storke wanted a library-museum," says Anderson. "He believed in creating a building to contain the printed word as well as artifacts of the past."

When he learned that the idea would be too expensive to implement, Storke championed the creation of a state-of-the-art library — one designed, Anderson recalled in a 1987 article in the *WPI Journal*, as "a campus showcase...what a building in WPI's future would look like."

Completed at a cost of $2.5 million (largely funded by a $5 million bequest from George C. Gordon, a Cleveland industrialist who graduated from WPI in 1895), the 65,000-square-foot Gordon Library brought all the information on campus together under one roof to be supervised by a staff of trained professionals. The building, the first campus structure to be centrally air-conditioned, became a model for other college libraries.

Gordon Library had space for 200,000 books and 450 patrons. It featured carpeted meeting and seminar rooms, a first-floor music room, space for the Institute's archives, and many areas for study or relaxation. While not Storke's vision of a museum, the library incorporated display space for paintings, photographs, prints and pottery in the lobby and in the wide third-floor corridor. The bottom floor housed the Worcester Area Computation Center (WACC). There were 1,700 students on campus and 40,000 books on the shelves when it opened in the fall of 1968.

Twenty-five years after its dedication, Gordon Library remains ahead of its time, although today it is almost as different from the building it was the day it opened as the new library was from the original disconnected collections. WPI's student population is now about 3,800 and the building is bursting at the seams with more than 350,000 volumes, nearly one million pieces of microfilm and microfiche, about 1,500 magazine and journal titles, and some 2,000 videotapes of course lectures.

"This library is a dynamic facility that meets the times and the needs of the people," says Anderson. "Thirty years ago a library was basically a collection of books, monographs, periodicals, reference materials and technical reports—mostly in paper copy. Over the years, microfilm came into existence, which saved space by putting materials on a single image that people could access with a special reader.

"As computers became more sophisticated, information could be stored in a different form, and a whole new world opened up for the user and the librarian," he explains. "As a result, the reference area of the library has changed drastically. There the printed word and the computer coexist to serve the patron. On the practical side, there is just so much basic material that can be stored in a college library. Our job is to open doors and windows to information in other libraries through on-line databases."

Throughout his WPI career, Anderson has made a point of ensuring that Gordon Library has always met the needs of its patrons. "Three decades ago a typical engineering student was taught from the text and the library wasn't really needed for undergraduate students—it served the faculty and the graduate programs.

"With the implementation of the WPI Plan, the whole concept of learning changed and this library became a major component

While it serves a much larger constituency than it did 25 years ago, Gordon Library has remained a state-of-the-art facility by embracing the technological advances of the computer revolution.

Chemical engineering graduate student Emel Inanc prepares to peruse a few of the 350,000 books housed in Gordon Library. Today, through a consortium of area libraries, students have access to more than three million volumes.

in that element of education. We had basic collections in the humanities and social sciences, but when the Humanities Sufficiency was added to the Plan we began cooperating with other Worcester academic libraries so we could share materials."

In 1968 Anderson became the first chairman of the Worcester Area Cooperating Libraries, a joint effort of 15 academic, public and special libraries sponsored by the Worcester Consortium for Higher Education. Its purpose was to facilitate the sharing of resources among member institutions and assist in the introduction of advanced library technology.

Through WACL, library patrons now have access to more than three million volumes and serial subscriptions. "Since 1974, WPI has participated in the Online Computer Library Center Inc., the world's largest and most comprehensive database of bibliographic information," Anderson says. "The installation of a campus computer network, along with active cooperation from the Institute's College Computer Center, has enabled the library to expand its services. Faculty members and students can now 'use' the library from any location that has a connection to the network."

"I have great respect for Al," says Susan Baughman, university librarian at Clark University's Goddard Library, which is part of the WACL. "He's forward-looking, very analytical, imaginative—and he very much believes in interlibrary cooperation."

Ever the pragmatist, Anderson views this cooperation as a way to put patrons in touch with as much information as they need. "Worcester is rich in museums and libraries and sources of information," he says. "It's almost unique to have so many colleges in the system. We could not exist without our current programs with Clark, Holy Cross and the University of Massachusetts Medical Center, supplemented by the Worcester Public Library, Worcester State College, Assumption College, the American Antiquarian Society and the Worcester Art Museum. And, of course, we can go one step further: less than 50 miles to the east are the collections of Harvard and MIT."

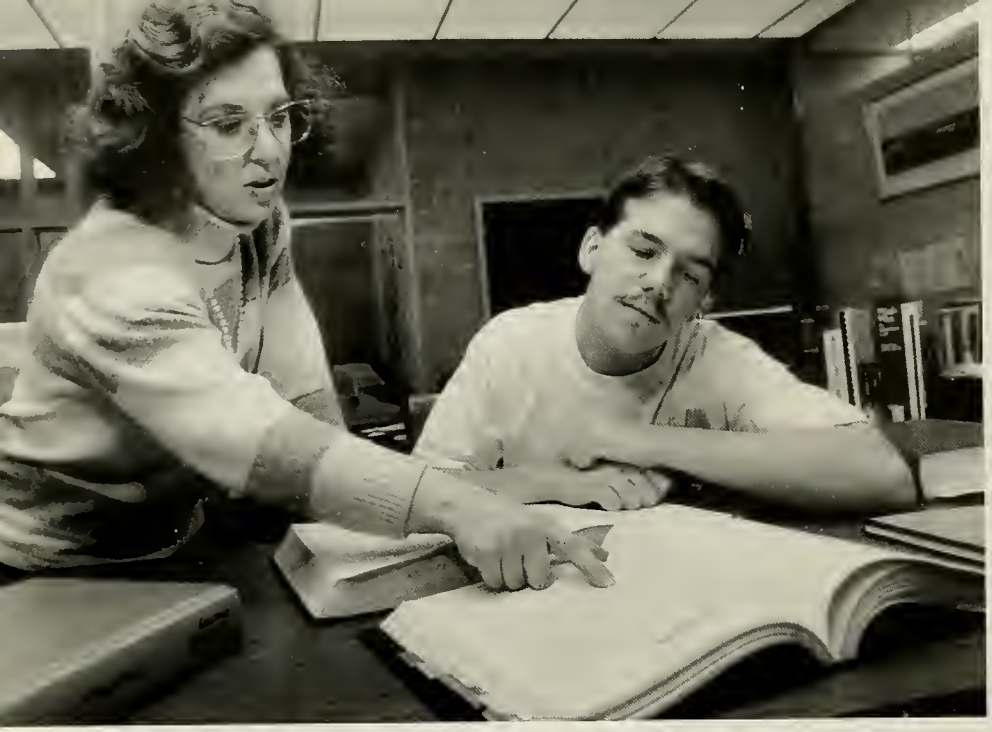
As head librarian, Anderson, who manages a staff of 30 and a budget equal to about 3 percent of the total Institute budget, says he views himself as a catalyst. "The heart of any library is its staff," he notes. "They interpret to a great degree what is in a collection. They help build a collection, and they help in utilizing the collection by the patrons. My philosophy is, let other individuals develop and let them set their mark, as long as it fits within the confines of the library.

"Our librarians have expertise and interests that contribute significantly to their work here. For example, Diana Johnson [reference and interlibrary loan librarian] has a degree in chemistry; Don Richardson [reference and technical reports librarian] has expertise in the area of bibliographic instruction through formal and computer programs; Margaret Riley [circulation librarian] and Deborah LaCroix [senior library associate/cataloger] are musicians.

"Lora Brueck [archivist, special collections librarian and cataloger] is a photographer who has brought many interesting exhibits to campus, and Helen Shuster [who will become interim head librarian after Anderson steps down] is an expert on automation. Carmen Brown [associate librarian and head, public services] ensures that all programs benefit the needs of the patrons, especially the students. They are the ones who pay the bills and enable us to serve. The result is that while Gordon Library is small and has a small staff, it has done more to innovate than some of the larger libraries in the country."

"Although he doesn't say too much, Al Anderson is very supportive of his staff," says Diana Johnson. "My feeling is that he cares about us very much; I know he is always open to new ideas that are properly proposed."

Anderson says his successor faces some significant challenges. "The library is run-



Scott E. Lewis '95 receives some help in his search for information from reference librarian Joanne L. Williams. Williams and the library's other 29 staff members are the "heart of the library," notes director Al Anderson.

ning out of space. We need to expand shelving for books and periodicals into the 10,000 square feet of space on the lower level that was used by the College Computer Center until Fuller Laboratories was completed in 1990. We need to create additional reading space for patrons, space for our staff, and space for the ongoing changes in technology. The building is tired. Its heating and air-conditioning system needs to be replaced, and the furniture needs to be renovated to create a fine aesthetic place that's enjoyable to be in."

Despite the challenges, Anderson says this is an excellent time for someone to step into his shoes. "We're on the cutting edge of changes in library information," he says. "The whole aspect of adapting a building to meet the changing needs of the patrons is exciting."

The new director will succeed, Anderson believes, if he or she continues the concept of the library "as a service organization, with staff members who are willing to adapt as adaptation is needed, and willing to be of service to whoever needs it."

Anderson's own interests are reflected in the library's collection of materials about author William Faulkner, which he describes as "equal to, if not better than, almost any other collection in the city." It can also be seen in an excellent art and architecture collection, which serves the Worcester Art Museum, as well as art students at various other colleges.

"My opinion of Al is that he is truly a gentleman in the accepted aristocratic sense of the term," says Louis J. Curran Jr., associate professor of music, who has been Anderson's friend since the librarian first joined the staff. "Al has a splendid eye for antiquities and things of beauty, which is reflected in the number of displays and exhibitions in the library.

"While he would never mention the fact, Al was instrumental in preserving the portraits of the college fathers. I found them in disastrous condition in the Boynton Hall tower. Al arranged for them to be restored at the Worcester Art Museum and hung in the great hall of Alden Memorial, where they were recently returned when renovations to that building were completed.

"He's private even with his friends, but is extremely kind," Curran adds. "He and his wife were a great help to me when I was in the hospital a while back. He also has a piquant sense of humor and he loves plays on words."

Anderson and his wife, the former Ann Lee O'Connell of Worcester, live with their daughter, a college student, in Holden, Mass., where they are active in several area organizations. "Retiring won't be any big deal," he says. "I'm looking forward to it. I hope to volunteer, but not necessarily in the field of librarianship. My work at WPI has been very pleasurable, but in retirement I'll detach myself from that and go into something totally different."

ABRACADABRA

These days a good library is like a magician's top hat. While prestidigitators amaze their audiences by pulling doves, rabbits and scarves from tall black hats, today's librarians bring forth a vast universe of up-to-date information on virtually any topic from a constantly expanding system of computers and electronic networks.

David Cyganski '75, professor of electrical engineering, has witnessed the changes that the Gordon Library has undergone over the past two decades. Cyganski enrolled as a freshman in 1972 and went on to earn a bachelor's, a master's and a doctorate. He joined the faculty in 1980 and from 1989 to 1991 was vice president for information systems and services and vice provost, a post that included oversight of the library budget.

"A good engineer uses the library every day—for research, for information, and to make classroom learning easier and more meaningful," Cyganski says. An avid reader with an interest in a wide range of scientific and technical topics, as well as music and gardening, he says he is probably one of the library's biggest patrons. He borrows books and has articles copied almost every day, and says he appreciates the changes Al Anderson has brought to Gordon Library.

"Nowadays, it's a whole new world," says Cyganski. "We're at the pinnacle of on-line service, because of the way the library has embraced the computer. All a person has to do is log into our campus network and type 'library' to gain access to the world's largest on-line database. Without ever leaving your desk you can search the library's entire on-line catalog and the catalogs of more than 30 other schools. You can find out where a paper or publication is held and arrange for all sorts of materials to be delivered, faxed or photocopied."

Jeffrey A. Bloom '87, a WPI student since 1983 (he has completed his bachelor's and master's degrees in electrical engineering, the latter in 1990, and is now working on his Ph.D.), uses a modem to tap into this wealth of information from his home. He says the library's electronic services have come a long way since his

Electronic Sleight of Hand Brings Users a Universe of Knowledge

Archivist Lora Brueck, standing, helps a student learn to use the Gordon Library's on-line catalog, which replaced the card catalog. With computers, patrons can now access a wide range of information from libraries all across the country.

early years as a graduate student. Back then, he notes, only a few databases could be searched with computers that were sometimes difficult to use.

"Because of those limitations, computers were just a supplement to the more traditional information search using the card catalog," he says. Today the card catalog itself is accessed with a computer.

Cyganski illustrates the speed and user-friendliness of the library's on-line services by accessing *UnCover*, a magazine database available through the Institute's computer network. He types in a request for information about Papoulis' Generalized Sampling Algorithm and in less than 10 seconds the computer searches through some 10,000 journals to produce a list of articles and their locations.

While the computer network allows him to spend less time there these days, Cyganski says there is still ample reason to visit the library building. "When students complain they are having trouble understanding their textbooks, I tell them to go to the library and look through other books that cover the same material," he notes. "There's always a big selection—there may be as many as 150 books on a particular topic. I tell these students to look through these other books until they find one that speaks their language, and to use that book to help follow the lectures."

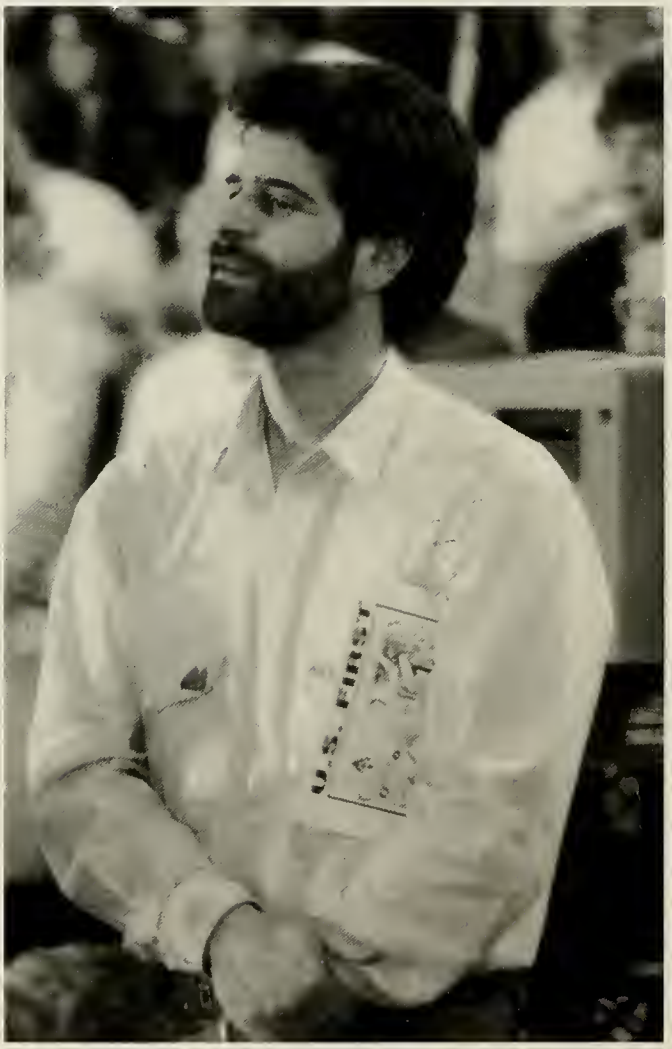
Bloom says he's used the library in just this way. "As an undergraduate, I appreciated being able to go to the audiovisual room and watch a lecture on videotape. It was a real help to be able to see a professor (even if it wasn't the one who was teaching your course) explain the material and pinpoint the things you didn't understand. You could always rewind the tape if you needed to clarify the topic or problem."

Cyganski says the new library technology has also changed the way he teaches. "I expect my project students to be able to do more—to check more references—and as a result, to present work that is better considered and more organized. Being able to access everything everyone else has done on a particular topic allows you to be more original. It's bound to lead to better projects.

"You know," he adds, "Stanislaw Ulam said that the most difficult unsolved problem in mathematics is knowing whether someone has solved it before. In this age of library science, the computer is helping users tackle that dilemma."

—Bonnie Gelbwasser

Lighting a Fire in Young Minds



PHOTOS BY NEIL NORUM

Successful entrepreneur Dean Kamen wants to help young people know the joys and rewards of science and technology.

It looks like Dean L. Kamen '73 will have to change his business cards. The cards identify him as Dean Kamen, N.D. The N.D., he says, stands for no degree, but the 41-year-old entrepreneur and science educator recently received an honorary doctorate in engineering from the institution he left two decades ago before finishing his bachelor's degree in physics.

In awarding such a prestigious honor to one so young, WPI recognized both Kamen's impressive professional accomplishments and his commitment to helping young people learn about the excitement of scientific discovery and the joy of creating new technology to solve real human problems—qualities that have been the driving forces in his own career.

Kamen credits at least some of his fascination with science and engineering, as well as his love of hard work, to his father, a free-lance cartoonist and illustrator, and his mother, a teacher of bookkeeping and accounting (both help out today with his various businesses). Jack and Evelyn Kamen encouraged all four of their children to indulge their imaginations and natural curiosity about the world.

More often than not, while their friends read comic books and played baseball, Dean and his older brother, Bart (now a physician), could be found in the cellar of the family home on Long Island with their Erector Sets, model trains, slot cars, chemistry sets, photographic equipment and electronics.

By the time he enrolled at WPI in 1969, Kamen's curiosity and imagination had already begun to bear fruit. With Bart's help, he designed a portable medical infusion pump called the Auto Syringe. The device gives diabetics and other patients whose lives depend on frequent doses of medication a greater degree of freedom. It also lets the terminally ill receive pain-killing drugs in their own homes. In hospitals, the pump relieves nurses from having to constantly monitor transfusion patients.

As news of Auto Syringe spread through the medical literature, the product became a huge success and Kamen found he was spending too much time running his business to attend classes. Still, he managed to engage selected professors in spontaneous four-hour discussions in their offices. (He and Harold W. Hilsinger, associate professor of physics, still brainstorm occasionally.)

The business soon outgrew the family basement, so Kamen moved it first to a nearby industrial park, and then to Hooksett, N.H. In 1982 he sold Auto Syringe in a multimillion-dollar deal to Baxter Health Care Corp., a subsidiary of Baxter International, but he kept the research and development end of the business, named DEKA Research and Development Corp., and set up shop in Manchester, N.H.

Kamen also owns three buildings in Manchester's old Amoskeag millyards, as well as Telectrol Systems, which manufactures energy management, automation control and digital control systems, and Enstrom Helicopter, a Menominee, Mich., company that builds helicopters sold and serviced by companies around the country, including Copters Unlimited in Laconia, N.H., which Kamen owns.

In 1986 he purchased North Dumpling Island off the Connecticut coast. He rents the two-acre island, which has a renovated lighthouse with its own desalinization plant and generator and a replica of Stonehenge built by a former owner, to corporations and individuals for conferences and other events. To them, Kamen

is Lord Dumpling, who edits his own tongue-in-cheek newspaper, issues visas, and even prints his own currency, called dumplings.

Although he is king of his own island, Kamen has down-to-earth ideas on how to boost interest in science and technology in the United States. All of the income he realizes from renting his island is used to fund U.S. FIRST (Foundation for Inspiration and Recognition of Science and Technology), an organization he founded in 1989. Designed along the lines of the U.S. Olympic Committee, the not-for-profit alliance of business, education and government leaders seeks to promote science and mathematics literacy by sponsoring special events for young people across the country.

Kamen and associate professor Harold W. Hilsinger (left) have shared many a long talk about physics since Kamen's days as an undergraduate at WPI.

Recently, it held the first Maize Craze, through which dozens of companies and universities—including AT&T, Boeing, IBM, Xerox, Harvard, MIT and WPI—adopted high schools in their communities. Engineers from each institution helped students design and build remote-controlled vehicles made from kits of motors, controllers and related materials provided by U.S. FIRST. The vehicles competed in Manchester to see which could pick up the most tennis balls in a set amount of time while maneuvering across a floor littered with cracked corn.

First place went to the Clinton (Mass.) High School team sponsored by NYPRO Inc., whose president, Gordon B. Lankton, is a WPI trustee. In second place was a team from Doherty High School in Worcester, which was sponsored by WPI. The winners received their awards from D. Allan Bromley, science and technology advisor to President Bush, and the Clinton team was invited to the White House to meet with the president.

Kamen also founded the Science Enrichment Encounters Museum (SEE) at his Technology Center in Manchester. He says the museum is his way of sharing with young people his passion for the natural world. An avid reader of the original works of scientists like Archimedes, Galileo and Newton, Kamen says he wants to persuade a new generation of children that superconductors can be just as interesting as the Super Bowl. "If I could convince children who are enamored of football to pursue science first, later they could buy the NFL and put it in their backyard," he says.

Kamen says his own goal in life is far removed from the NFL or even the success of his own bustling business empire. "I hope when I die that I will leave the world with significantly less ignorance," he says.

—Ruth Trask

Nicole Weiner, center, and Scot Trudeau, right, of the Doherty High School team watch as their robot's take of tennis balls is tallied during the Maize Craze.

Inside:

A tribute to discovery and the many WPI alumni who, as scientists and inventors, are opening up new frontiers of knowledge and understanding, and proving that—500 years after Columbus first set sail—there is no shortage of unknown territory yet to explore.

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New Worlds Of Computing

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Front Cover: A supercomputer was used to assemble this view of Venus from data sent back to Earth by the Magellan probe. Building the next generation of high-performance computers is the goal of WPI's new Center for High-Performance Computing. Story on page 10. Photo courtesy of NASA. **Opposite:** A summer scene in front of the "Wedge" between Daniels and Morgan halls. Photo by Janet Woodcock. **Back Cover:** Alumni of the classes of 1942 and earlier enjoy the annual 50-Year Associates Dinner in the great hall of the newly renovated Alden Memorial during Reunion in June. Watch for a photo essay on the restoration of Alden early next year. Photo by Janet Woodcock.

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A Trillion Here, A Trillion There...

The late Senator Everett Dirksen is alleged to have said once, "A billion here and a billion there and pretty soon you're talking big money." Maybe it's inflation, or perhaps it's the nature of progress, but a billion just isn't what it used to be.

Once upon a time Americans gasped at multibillion-dollar federal budgets; now our budget deficits alone run into billions—some 400 billion at last report. As for the budgets themselves, they've already broken through the $1 trillion mark and they show no signs of stopping there. Major corporations now measure their revenues in billions of dollars, tapping into markets for consumer electronics, cars and computers that run well into the trillion-dollar range.

It may simply be beyond our capacity to visualize very large numbers like the 100 billion stars in the known universe or the trillions of instructions high-performance computers may soon be able to process in the space of a second.

It seems that if you want attention these days, you'd better be talking trillions. That is especially true in science. Chemists once seemed content to measure things in parts per billion, but now they routinely hunt down that one atom in a trillion. A new accelerator under construction in Texas will push subatomic particles along with an astounding 20 trillion electron volts of energy (assuming it doesn't get cut out of that $1 trillion-plus federal budget). And, as you'll read in our cover story, computer scientists are now souping up their computation engines with hopes of breaking the trillions-of-instructions-per-second barrier.

But what's most amazing about this rush to count higher, measure finer and compute faster is just how blasé we've become about really big numbers. As we casually bandy about the latest federal budget proposal or the newest advance in scientific technology, do we really know what we're talking about? Does anyone truly know how big a trillion is?

Sure, on paper it seems simple. A trillion is 10^{12} or the number 1 followed by 12 zeros. Looked at another way, it's a million million or a thousand billion. But frankly, knowing that doesn't make it any easier to visualize. The fact of the matter is, it simply requires more imagination than the human brain can muster.

It would seem we are most comfortable with numbers we can see. For example, on a clear, dark night you can see up to 6,000 stars with the naked eye (depending upon how good your naked eye is). That's a reasonably big number, but you can still see it. There they are—6,000 stars. But tell someone that there are another 100 billion stars out there in the known universe that he can't see, and you may as well be talking about the number of angels dancing on the head of a pin.

In cases like this, science writers naturally turn to comparisons. For big numbers, the comparison of choice seems to take the form, "if a trillion objects (bricks, volleyballs, science writers) were laid end-to-end or stacked like cordwood, how far would they stretch?" In his delightful children's book, *How Much is a Million?*, David M. Schwartz uses this and other approaches.

In words and illustrations, Schwartz tells his young readers that a million kids perched on one another's shoulders would stand more than 46 times taller than the highest plane has ever flown; a billion kids would stretch three times as far as the Moon; a trillion kids would nearly reach the rings of Saturn. What if you wanted to count to a trillion? Schwartz asks. Well, counting to a million would take 23 days. Counting to a billion would take about 95 years. And, if you could keep counting for more than 190,000 years, you might just reach a trillion.

It's pretty clear that no matter what comparison you choose, you've got to use some pretty big numbers or expansive concepts to convey the idea of a trillion. Just how far are the rings of Saturn, anyway? (They're about 800 million miles away from Earth, in case you didn't know—it took the first Voyager probe 38 months to reach them). How long is 190,000 years? (If you could go back that far in time you'd find *Homo sapiens* still in the process of evolving from our ancestral species on the plains of Africa.)

Perhaps it is enough simply to be amazed by concepts like a trillion—to know that they are beyond our ability to understand (which is, in itself, a sort of understanding). Perhaps by over-analyzing, we lose the sense of childlike wonderment that goes along with thinking about the astounding scale (both small and large) of the universe around us. As playwright Eugène Ionesco once wrote, "Explanation separates us from astonishment, which is the only gateway to the incomprehensible."

—Michael Dorsey

"Where is the Money Going?"

To the Editor:

I am truly amazed at the lack of outcry about the way WPI spends its money. Either nobody reads the *Journal*, or nobody really cares. I'm not sure which I find more frightening.

In the Winter 1992 issue I found an article entitled "Climbing Between the Peaks." In it I discovered yet another pitch to alumni for more money. The justification presented was incredibly weak. However, what really disturbed me was Table 2 (reprinted here). WPI's endowment has increased by roughly 6 percent per year in *constant dollars* since 1985!

That means endowment funds have increased by over $2 million each year after inflation is accounted for. Tuition revenue has increased by almost 8 percent each year *after inflation!* And still our beloved alma mater cannot make ends meet. Where is the money going? Industry salaries have not even come close to keeping pace, before inflation. Entry-level salaries—in constant dollars—have actually decreased over the same period.

In the Summer 1991 issue of the *Journal* I found an article that proudly trumpeted WPI's $450,000 landscaping budget. Even at the ludicrous current tuition rate, a 50 percent cut in landscaping would pay for 10 full scholarships. I have been told the landscaping is necessary to attract students. I suggest the best way to increase enrollment is to reduce tuition.

In times of recession, real-world organizations must carefully consider and prioritize their spending. Everything must be evaluated for its contribution to the core business. If you are truly planning for future growth, you should first market your organization carefully. What could be a better marketing tool than a satisfied alumnus? I suspect alumni are responsible for far more enrollments than shrubs or stone monuments.

Second, you should invest only in facilities and tools directly related to current production, as well as in research devoted to advancing your future business. I'm sure a renovated Alden Memorial will be beautiful, but how does it contribute to engineering and science education? Alden is a fringe benefit, not a prerequisite.

The third thing you should do is carefully invest in areas that will produce revenue indefinitely. A large portion of WPI's income comes from alumni. Why not invest in programs that produce more alumni? How much income does Alden Memorial generate yearly? How much will we get from the new headstone on Institute Road?

In my opinion, the priorities for spending should be (1) student financial aid or tuition reduction, (2) faculty compensation, (3) direct-impact facilities such as classrooms, laboratories and student housing, and (4) administrative expenses. All other items are optional, and should be paid for by alumni who think them important.

I believe WPI is not being managed responsibly. I call on the administration to justify how it can spend millions of dollars each year on things like landscaping and marble facades when there are thousands of bright, creative kids in desperate need of scholarship aid.

If there is not enough money to go around, I recommend administrative staff and salary cuts. That's what we are facing in industry today. When intelligent businesspeople are short on resources, they cut overhead, not production. If WPI's administrators cannot find a way to live on a budget that increases every year—even after inflation—they should resign in favor of others with the necessary competence. I might suggest that future hirings be made from industry, rather than academia. WPI could use a large dose of real-world expertise.

If you agree, I suggest you contact the administration and let them know. Consider designating your contributions to WPI for financial aid only. If you disagree, contact them anyway. They need to know someone is keeping an eye on them. The time for fiscal responsibility at WPI has come, and it's going to be here for a good long while.

Peter M. Schoonmaker '80
Woburn, Mass.

TABLE 2. SOME REPRESENTATIVE CHANGES IN ASSETS, REVENUE AND EXPENDITURES AT WPI

	FY1985* (in millions of dollars)	FY1991* (in millions of dollars)	Change (in percent)
Endowment	38.2	51.3	34.3
Tuition/Fees Revenue	12.4	18.3	47.6
Total Revenues	27.3	32.7	19.7
Instruction & Library	7.8	10.1	29.5
Financial Aid	3.9	6.3	61.5
Operations and Plant Maintenance	2.2	2.2	0

*Constant dollars, Basis: 1978 (Source: 1990-91 WPI Annual Report)

Hitting the Ceiling

To the Editor:

The Spring 1992 issue was an excellent one. I particularly enjoyed your series "The Discoverers." But I was seriously jarred when I came across the term "ceiling wax" (page 5, column 2).

I'll grant that sealing wax (once widely used to seal letters, batteries, jars and, possibly, vacuum systems) is not often seen these days. But how often do you see anyone waxing a ceiling?

I hope there are a few literate engineers still around, and that I'm not the only one who noticed.

Charles H. Chandler '84
Lexington, Mass.

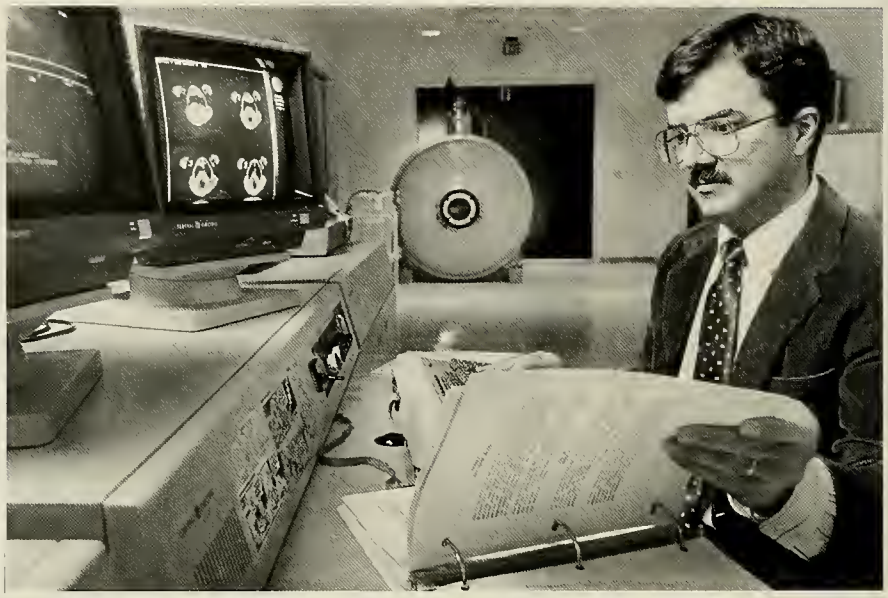
MAKING CANCER KILLERS EVEN DEADLIER

While the many forms of cancer that can attack the human body remain major killers, treatments that employ carefully administered doses of radiation or chemical agents have proven highly effective in destroying tumors and prolonging the lives of cancer victims. But the success of radiotherapy and chemotherapy strongly depend upon the degree to which tumor cells are oxygenated, a condition that has proven difficult to either measure or control.

With a three-year, $180,000 grant from the Biomedical Engineering Research Grants Program of The Whitaker Foundation of Mechanicsburg, Pa., Christopher H. Sotak, assistant professor of biomedical engineering, is developing a new noninvasive technique for measuring tumor oxygenation that should make cancer treatments more effective. The method employs magnetic resonance (MR), a powerful diagnostic tool that combines a strong magnetic field and radio waves to produce highly detailed images of the body.

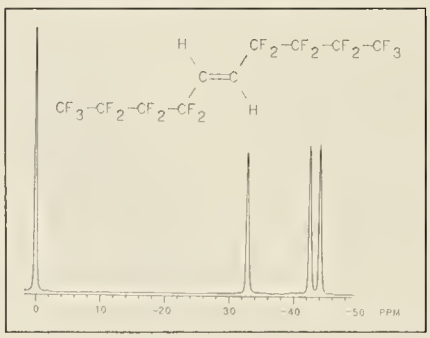
Radiation and many types of chemotherapy are most effective when tumor cells receive adequate levels of oxygen (a few chemical agents actually work best when oxygen levels are low). Radiotherapy works by removing electrons from the DNA of tumor cells. If molecular oxygen is present, it binds to the sites from which the electrons were removed, preventing the cells from either carrying on life-sustaining functions or reproducing.

Unfortunately, the rapid growth of most tumors outpaces the ability of the body to supply them with oxygen. As a result, cancer cells that are not near blood vessels tend to be oxygen deprived, a condition known as hypoxia. To overcome this problem, radiotherapy is usually administered in a series of doses, with the first dose killing well-oxygenated cells that lie near blood vessels and subsequent doses attacking more distant layers of previously hypoxic (and hence radioresistant) tumor cells that frequently become reoxygenated after the death of the intervening cells.



JANET WOODCOCK

Above, Sotak in WPI's Magnetic Resonance Imaging Laboratory. Below, the magnetic resonance spectrum for a perfluorinated hydrocarbon. This spectrum changes in response to changes in tissue oxygenation, making these compounds ideal noninvasive probes for this parameter, which can affect the success of cancer treatments.



"The problem is," Sotak says, "tumors reoxygenate at different rates. The ideal time to administer another dose could be several hours later or several days later. We'd like to be able to monitor the time course of reoxygenation and determine the most efficacious time to administer subsequent doses."

To increase the effectiveness of any one dose of radiation, physicians can use chemicals called adjuvants that prepare the tumor by increasing the oxygen flow to the hypoxic cells. But gauging the effectiveness of adjuvants in the laboratory has proven a difficult, laborious process and their effectiveness in actual practice is not well understood, Sotak says.

Using the method he is developing in WPI's Magnetic Resonance Imaging Laboratory at the Massachusetts Biotechnology Research Park in Worcester, Sotak says it should be possible to accurately monitor changes in tumor oxygenation after an adjuvant is administered and determine the optimal time after its injection to start radiation.

Sotak's method makes use of chemicals called perfluorinated hydrocarbons, which, because they can dissolve up to 50 percent of their own weight in molecular oxygen, have been employed for many years as artificial blood substitutes. When administered as emulsions in large doses, perfluorinated hydrocarbons will accumulate in the reticuloendothelial system of the liver, spleen and bone marrow. But they are also captured by macrophages, cells that protect the body from infection and foreign particles.

Because macrophages tend to congregate at the sites of tumors, Sotak in earlier research was able to use perfluorinated hydrocarbons as contrast agents—chemicals that make tumors stand out more readily in MR images. But what makes them especially valuable in his current research is the fact that a property of the signal they emit in an MR scanner is directly proportional to the amount of oxygen in the tissue surrounding them. That makes them ideal noninvasive probes for measuring tumor oxygenation.

In work already completed, Sotak and a team of graduate students that includes Paul S. Hees (who will receive his Ph.D. in biomedical engineering from WPI this summer), Bernard J. Dardzinski, and Limin Li, a postdoctoral fellow in physics, have used perfluorinated hydrocarbons to measure oxygen levels in tumors and have monitored changes in tumor oxygenation following the administration of nicotinamide, an adjuvant for radiotherapy.

"We've convinced ourselves that the method works and that we can measure physiologically relevant changes in oxygen tension as a result of administering these pharmaceuticals," Sotak says. The next steps will be to study additional adjuvants and then to begin looking at how oxygenation within tumors changes after radiation or chemotherapy are administered, he adds.

The studies Sotak's research team has done to date have employed a technique called magnetic resonance spectroscopy, which measures the average oxygenation level for an entire tumor. Since oxygen levels can vary widely within the same tumor—a fact that may prove vital in planning a course of radio- or chemotherapy—Sotak is also developing a method that will display a color-coded, two-dimensional map of tumor oxygenation throughout a tumor. This technique should prove useful in evaluating spatial differences in the response of a tumor to treatment.

The ultimate goal of the project, Sotak says, is to translate the new technique and the software for displaying the oxygen map from WPI's research machine to the larger MR scanners used in clinical practice. To help make this transition, Sotak will work with Dr. Thomas Griffin, director of clinical research in the oncology division of the University of Massachusetts Medical School, who serves as a consultant on the work funded by The Whitaker Foundation.

Once in routine use, perfluorinated hydrocarbons should prove valuable in the evaluation of a host of other medical conditions—including heart disease and stroke—that are either caused by or result in changes in tissue oxygenation, Sotak says. "We believe this method will have a wide range of applications, and should open up new doors for clinical diagnosis and treatment."

The Whitaker Foundation was established in 1976 by the late Uncas A. Whitaker, founder and chairman of AMP Incorporated, now the world's leading producer of electrical and electronic connecting devices. Biomedical engineering has always been the principal focus of the foundation.

LASER PROTECTION IN THE BLINK OF AN EYE

Flying low above the Persian Gulf, a U.S. Navy pilot rolls his A-6 and descends toward an unidentified destroyer. As the plane levels off, the ship's crew switches on a laser tracking system and the beam catches the pilot squarely in the eye. Blinded and in pain, the airman loses control of his jet, which spirals into the gulf and explodes.

While that scenario is fictional, U.S. military planners worry that as lasers come to be employed more and more in modern weapons systems, the potential for disabling eye injuries among military personnel—whether accidental or caused by offensive laser devices—is growing apace. Of equal importance is the threat lasers pose to the delicate optical sensors often used in battlefield equipment.

Spurred by these concerns, the Pentagon has been funding efforts aimed at developing new forms of laser eye protection. This new technology should also find applications in civilian research laboratories, on the manufacturing floor, in medical facilities, and in other places where lasers are routinely used.

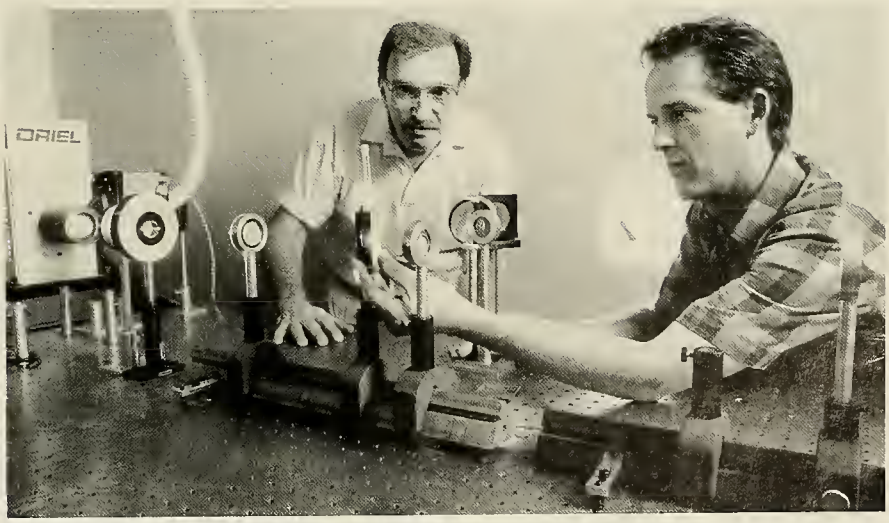
As part of this program, William G. McGimpsey, assistant professor of chemistry, and Stephen J. Weininger, professor of chemistry, are using a sophisticated laser technique to create chemical compounds that might be suitable for use in these new forms of laser eyewear. Over the past two years McGimpsey and Weininger have received nearly $200,000 in funding for their research from the U.S. Army Research, Development and Engineering Center in Natick, Mass.

One of the goals of this work is to develop eye protection that overcomes the limitations of laser goggles now commonly worn to protect the eyes from exposure to laser beams. "Laboratory eye protectors use colored filters to block out the intense light produced by lasers," McGimpsey says. "Unfortunately, these goggles greatly reduce the amount of light that reaches the eye and may also prevent a pilot or soldier from seeing certain colors, with potentially dangerous results."

In addition, McGimpsey says, conventional laser goggles can block only selected frequencies of light. Since many weapons systems now employ lasers that can be quickly tuned to any of hundreds of frequencies, the Pentagon wants to develop laser eyewear that can block a broad spectrum.

"Ideally, these goggles should be clear in normal light," Weininger adds, "but when struck by the beam from any laser should darken enough to cut light transmission by a factor of about 10,000. Then, just as quickly, they should become clear

JANET WOODCOCK



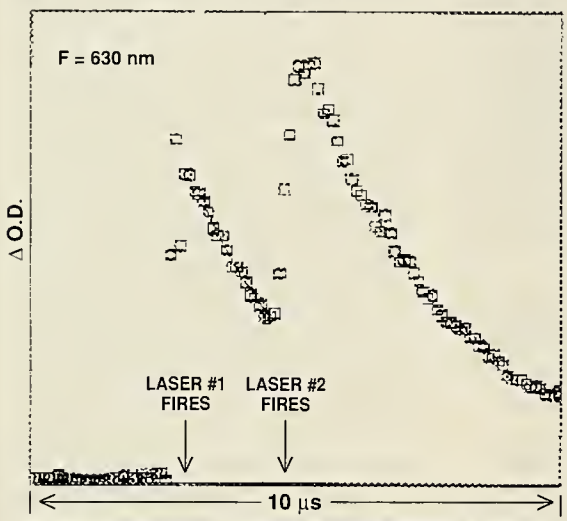
Weininger, left, and McGimpsey in the Laser Flash Photolysis Laboratory. McGimpsey holds a sample of a compound being evaluated for its potential use in a new form of laser eye protection.

again. This should all happen within a few trillionths of a second, so the person wearing the goggles won't even know anything has happened."

Finding chemicals that will meet those stringent requirements is a daunting task, McGimpsey says. To test candidates, he and Weininger are using a technique called two-photon-induced photoelectron transfer. The technique takes advantage of the fact that the coherent light from a laser is far more intense than normal light from lamps or the sun and can induce chemical changes that will occur only upon laser irradiation.

Working in the Laser Flash Photolysis Laboratory in the basement of Goddard Hall, the researchers first expose a chemical sample to a brief pulse of laser light. Molecules in the sample absorb a photon from this burst and are excited to a higher energy state. Before the sample can return to its original ground state, it is hit with a second laser pulse, which elevates it to a still higher energy plateau.

As the sample decays from this higher energy state to the ground state, it can undergo chemical changes that don't occur when the same chemical is allowed to decay from a lower energy state. While they are induced with two separate laser bursts in the lab, these two-photon reactions can also occur when a chemical absorbs two photons from a single laser exposure. Normal light, on the other hand, is too weak to cause such two-photon reactions.



In this example, a laser flash excites a compound to an elevated energy state. Before it can return to ground state, a second flash bumps it to a higher energy state.

The goal, McGimpsey and Weininger say, is to find chemicals that remain clear at lower energy states, but which become opaque when bumped to a higher energy state by laser-induced two-photon reactions. So far, the chemists have tested about a dozen candidate molecules. To determine which organic compounds to test, Weininger, whose specialty is organic chemical synthesis, begins with the qualities desired in the final product and then works backward on paper through the intermediate, light-induced chemical reactions to arrive at a promising starting point.

The chemicals Weininger synthesizes are actually systems that include electron donor and electron acceptor molecules. The transfer of electrons between the chemicals in these systems allows them to quickly return to their clear ground states after they have been darkened by laser light.

Because it is unlikely that any one chemical system will respond to all frequencies of light, McGimpsey and Weininger say the goggles that may ultimately result from their work will probably consist of multiple thin layers of polymer, each of which will respond to a different frequency or band of frequencies. As the work progresses, they hope to begin testing candidate chemical systems to see whether they can be successfully incorporated into clear polymers.

McGimpsey, who has been working with two-photon reactions for several years, says the techniques he and Weininger are using in this project have many other applications. For example, in photochemical machining, two intersecting lasers tuned to different frequencies can be used to create highly complex molds by causing two-photon reactions in specific areas of a polymer. The reactions degrade the affected molecules, which can then be easily removed, leaving behind precisely hollowed-out spaces.

The Laser Flash Photolysis Laboratory includes a pulsed Nd/YAG laser, a tunable flashlamp-pumped dye laser and an Excimer laser, all integrated and controlled by a computer system. The three-year-old lab has been equipped, in part, through grants from the U.S. Army and the Petroleum Research Fund.

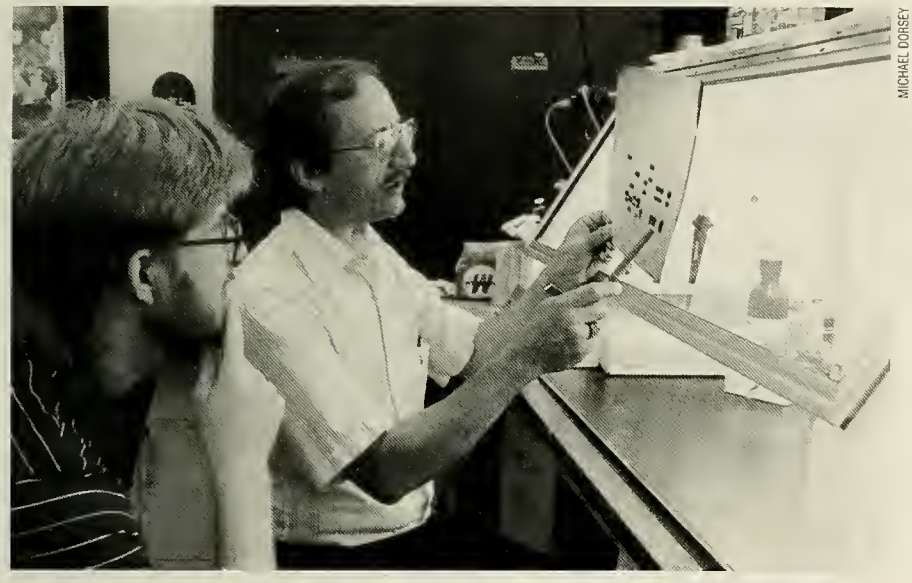
GENETICS AND THE GREAT SHRIMP DEFICIT

What type of seafood is favored over all others by people in every corner of the United States? If you guess shrimp, you're right. Each year Americans gobble up millions of pounds of these squiggling marine crustaceans. To satisfy that gargantuan appetite, huge quantities of shrimp must be imported each year from other countries. In fact, only 30 percent of the shrimp Americans consume each year is caught or grown in the U.S.

In part, this need for foreign shrimp—a need that results in an annual trade deficit exceeding $2 billion—is due to the fact that the species of shrimp Americans favor—*Penaeus vannamei*—grows only in warm water and can, therefore, be harvested only in the southernmost states. This requirement for warm waters has also limited shrimp farming in the U.S. to a few locations in Florida, Hawaii, South Carolina and Texas, with the result that only a tiny fraction of the annual U.S. shrimp consumption—about one hundredth of a percent—comes from these farms.

To find a way to reduce the annual shrimp trade deficit, the Gulf Coast Research Laboratory Consortium, a group of eight university and independent laboratories, has launched the U.S. Marine Shrimp Farming Program. The goal of the consortium, which includes the School of Veterinary Medicine at Tufts University in Grafton, Mass., is to improve the productivity of U.S. shrimp farms by developing high-quality, disease-resistant strains of *P. vannamei* in much the same way that agricultural experts have developed robust strains of poultry and livestock over the years. Funding for the program is being provided by the U.S. Department of Agriculture.

One thrust of the program is to find strains of shrimp that can resist viral diseases that have already wiped out shrimp



MICHAEL DORSEY

Buckholt, left, and Bagshaw examine a Southern blot from the shrimp *Penaeus vannamei* (the blot is shown below). The dark bands on the blot correspond to specific fragments of DNA. The technique is used to look for genetic markers in the shrimp genome.

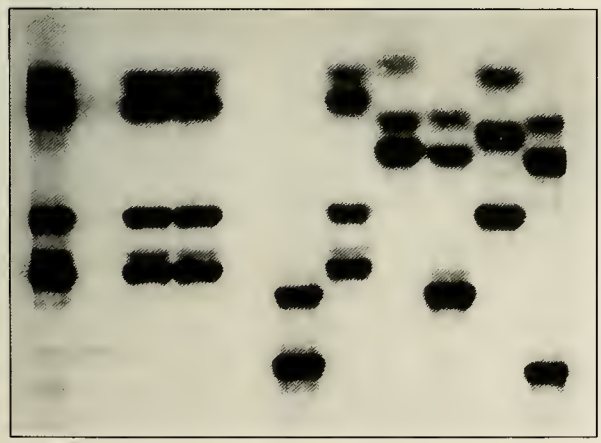
production in Taiwan and now threaten not only the farming industry in Southeast Asia and Central America—the largest such operations in the world—but wild shrimp populations, as well. In addition, the consortium hopes to gain a better understanding of the genetics of *P. vannamei* in hopes of finding genetic markers linked to qualities that enhance shrimp growth and hardiness.

Under subcontract to Tufts University, Joseph C. Bagshaw, professor and head of the Biology and Biotechnology Department, is tackling the latter task. Bagshaw, who has spent the last two decades studying the genetics of the genus *Artemia*, which includes brine shrimp—small crustaceans often used as food in aquaculture and in home aquariums—is one of the world's foremost experts on crustacean molecular genetics.

"I have a freezer full of *Artemia* clones that we can use as genetic probes in this work," Bagshaw says. "I also know how to work with these genes, and I know some tricks we can use to get these answers faster." Those tricks will come in handy as Bagshaw and postdoctoral fellow Michael A. Buckholt, who recently completed his Ph.D. in biology at WPI, attempt to locate suitable markers in the shrimp genome, a process Bagshaw likens to finding a needle in a haystack.

"We'll be using the same techniques geneticists use to find the genes for human diseases," Bagshaw says. "But unlike those searches, where the basic biochemical defect is often understood, we have no idea what makes shrimp grow faster or larger. We'll have to do it pretty much by hunt and peck."

In his research on *Artemia*, Bagshaw became the first geneticist to find repeated sequences—segments of DNA that are repeated over and over again—in the genome of a crustacean, and he says he and Buckholt will most likely find similar sequences in *P. vannamei*. If so, these sequences might be employed as markers, Bagshaw says.



A marker is a gene that lies near the gene for a disease or other characteristic one is studying. Because of their proximity, the genes are said to be linked because they are rarely separated when segments of DNA change places or cross over during cell division. The researchers will find out how well the repeated sequences work as markers by seeing if they are linked to genes that give shrimp the ability to grow even faster.

"We'll have to do some honest-to-goodness shrimp genetics," he notes. "We'll breed the shrimp and test them for the presence of the markers, and then see which of the markers always shows up in the fast-growing individuals. It's a lot of empirical work."

Once enhanced growth characteristics can be linked to specific markers, Bagshaw says, the chromosomal regions adjacent to these markers can be examined in more detail in an effort to characterize the specific genes that impart those favorable characteristics.

Bagshaw will also search the shrimp genome for a class of genes found in most organisms that seem to be related to growth. Research has shown that small segments of these so-called homeotic genes are almost identical from one species to another. Using a technique called the polymerase chain reaction, Bagshaw and Buckholt will zero in on these segments and then clone the regions around them many times over to get enough DNA to study.

"The genes in these regions should be associated with shrimp growth," Bagshaw says, "though we won't know exactly how. But they are obviously going to be desirable markers for favorable growth characteristics."

Armed with the knowledge that will come out of Bagshaw's lab, shrimp farmers should be able to develop new strains that will enable them to grow more shrimp and to get them to market faster (the process now takes about six months). Using similar techniques, other researchers are hoping to find genes that will give the shrimp a selective resistance to disease. "This research should give the U.S. a virtual monopoly on the production of superior strains of high-quality, specific-pathogen-free shrimp," Bagshaw says.

But his research could be taken one step further, he adds. "I would like to think about the prospect of literally genetically engineering shrimp the way we now engineer other domestic animals," he says. "We could produce shrimp that can grow even faster—maybe even shrimp that can grow well in the colder waters of the rest of the United States. I think this will be doable someday."

—Michael Dorsey

Designing Better Ups and Downs

Major Qualifying Project (MQP) by Heather M. Harrington '92, Peter A. Manor '93 and Sean P. Moore '92.

Advisor: Frank D. DeFalco, professor of civil engineering.

Standing, from left, Manor, Moore and Harrington. Randall W. Levere '93, seated, created the simulation seen on the screen.

It's been said that what goes up must come down. That's especially true of roller coasters, where the secret of a thrilling ride is not only how high up you go, but how fast you come down—and, of course, the lifts, loops, banks and curls in between.

With guidelines, specifications and designs provided by two roller coaster companies, and with the benefit of their own research into roller coasters at Busch Gardens, Disney World, and other theme and amusement parks, civil engineering majors Harrington, Manor and Moore used computer-modeled structural analysis and design techniques to plan their own steel roller coaster. Theirs was one of three projects in civil engineering to receive WPI's 1992 Provost's MQP Award.

In their report, the students explain that it is not speed alone (up to 60 miles per hour in some rides) that gives roller coaster riders that characteristic rush of adrenaline. Through strategic twists and turns, the truly great rides keep passengers in suspense by preventing them from seeing too far ahead. This limited line of sight provokes screams of terror and delight by creating the illusion that the cart is about to collide with a steel girder or careen off the track, until—at the last moment—it miraculously veers off onto a safer path.

To design their roller coaster, the students used ISDS/STAAD, a structural engineering program. In completing the design, they considered the geometry of the track, the effects of varying the heights of the peaks, the gravitational forces that would be experienced by the carts and their passengers, and the various loads on the structure—including those created by wind and ice. They also had to think about the thrill the design would provide riders and about the aesthetics of the finished product.

"Roller coasters have to appeal to the eye of potential riders," they say. "The best ones have some sort of geometry that will make spectators want to experience the ride—things like vertical loops and corkscrew-like sections."

At 283 feet long, 106 feet wide and 85 feet high, the students' roller coaster would fit on an average football field. It would begin with a lift and then a drop of more than 73 feet, which would provide the momentum needed to propel the cart through the remainder of the 1,202 feet of track. Traveling at an average speed of 25 miles per hour and hitting a top speed of just over 45 miles per hour, riders would experience one vertical and one horizontal loop before reaching the end.

"Civil engineers most often deal with project management, water works, the environment, roads, parks, subdivisions and bridges," the students say. "Structural engineering is one aspect of civil engineering that can provide solutions to a host of other construction-related projects. One less obvious challenge is the roller coaster."

For the student team, the roller coaster project was a chance to use modern technology and sound design principles to break new ground. In their words, "this project provided the opportunity to use a civil engineering education to engineer a solution to a problem that does not have a textbook answer."

Flying by the Power of the Sun

MQP by Agnes Chan '92, Kwok-Hung Cheung '92, Kristin Conley '92, Paul Crivelli '92, Christian T. Javorski '92, Nancy P. Torrey '92, Michael Traver '92, Freddy Mathias Pranajaya '94, Jeffrey D. Rembold '93 and Sujay R. Setlur '93.

Project Director: Andreas N. Alexandrou, associate professor of mechanical engineering.

Advisors: William W. Durgin, professor of mechanical engineering; Ralph F. Cohn and David J. Olinger, assistant professors of mechanical engineering.

Graduate Assistant: Charlotte Cody '90 (master's candidate).

Environmental problems such as the depletion of the ozone layer are spurring scientists and engineers to consider solar power as an ecologically sensitive alternative to fossil fuels to power everything from automobiles to aircraft.

The students, working in four teams, designed and constructed the Multi-Purpose, Remotely Piloted Vehicle (MPRPV), a prototype of a design that could be used in surveillance and reconnaissance missions. The ultimate goal of the plane, which the students named "Surya," the Hindu word for sun, was to demonstrate the effectiveness of solar power as an alternative energy source.

In June the design team presented a paper on the MPRPV at the Eighth Annual Summer Conference of NASA/USRA University Advanced Engineering Design Program for Space and Aeronautics.

The University Advanced Engineering Design Program brings together NASA engineers and students and faculty from engineering schools around the nation by integrating current and future NASA engineering design topics into the university curriculum. Selected universities, including

Saving Time and Money

MQP by Michael C. Helm '92 and Elizabeth A. Plessis '92.

Advisor: Enio E. Velazco, assistant professor of management.

Sponsor: Digital Equipment Corp.

Digital Equipment Corp.'s Westminster, Mass., facility is the company's primary finished goods distribution and consolidation center in the U.S. Because of the tremendous volume of transactions processed at this distribution center, Digital has been working for several years to implement time- and money-saving improvements through its own total quality management program.

To improve competitiveness, the company must identify customer requirements and ensure that Digital personnel and processes meet those needs. In addition to producing high-quality, reliable products, Digital has recognized that customers' expectations must include accurate billing and fast, safe deliveries.

To address these issues, Digital has developed a methodology called AΔT to help employees decrease hidden waste in manufacturing and administrative processes. Digital requires that problems be addressed and solutions conform to ISO 9000, a certification that any company planning to do business with the European Economic Community must obtain.

Helm and Plessis were the first to introduce AΔT to employees at the Westminster warehouse. At the request of the sponsor, they focused on analyzing the receiving and storage processes for incoming material. In the course of their research they interviewed engineers and other Digital employees working in the process. They also examined the processes through observation and hands-on experience.

The students separated each step in each process, designed flow charts, compiled a list of forms, and identified potential areas for improvement within each process—such as idle time, double handling of goods, and bottlenecks. They determined that delays in data entry kept workers idle for short periods of time, and that delays in checking materials resulted in bottlenecks in quality control.

Their recommended improvements included moving data entry (currently housed in separate quarters) to the warehouse floor to eliminate lag time and enable data-entry employees to assume more responsibilities. They suggested eliminating duplicate forms, storing software in a single area, and, ultimately, converting to bar codes to identify all items in the warehouse.

From left are Helm, Velazco and Plessis.

"The work these students did at Digital was of great value to the company," says Velazco. "Digital was preparing to be audited for ISO 9000 certification at the time the students were working on their MQP in Westminster, and their findings assisted the company in improving this facility."

"Digital has a strong policy of involvement with local universities," says Ken Kaminsky, a logistics analyst at Digital. "By providing students an opportunity to gain real business experience, we benefit from their knowledge and application of the latest technologies. This project, one of four our facility sponsored this year, gave us a fresh look at the work we do. It has resulted in real process improvement."

From left with the Multi-Purpose Remotely Piloted Vehicle (MPRPV) are Chan, Conley, Traver, Javorski, Torrey, Crivelli and Cheung.

WPI, are aligned with various NASA centers. Students choose design projects in consultation with NASA, which provides technical expertise and guidance for the duration of the project. The projects must culminate in an oral presentation at the annual conference.

The WPI teams designed the MPRPV to perform a sustained figure-8 flight pattern at an altitude of 50 meters using only solar power. Four test flights at WPI's Alumni Field were videotaped and shown during the NASA presentation.

The plane was constructed by hand using composite materials, especially a carbon-fiber-epoxy laminate selected for its strength and light weight. The design resembles a glider and measures about 2.5 meters from tip to tail. Its wings spans 4.5 meters and support 120 solar cells donated by Mobil Solar Corp. The tail is constructed of balsa wood and plastic foam; its supporting spar is made of carbon-fiber composite materials.

"The test flights demonstrated the aircraft's stability and controllability," Durgin says. "During March the solar angle became sufficient to provide energy for the maintenance of level flight with a slight reserve for climbing. This thin power margin was the crux of the design effort. The trade-off between solar cell area and aircraft weight provided students a highly challenging design constraint."

—Bonnie Gelbwasser

THE SOUL OF A NEW CENTER

With the creation of the new Center for High-Performance Computing, WPI has become a major player in the hottest quest in computing—the race to develop a new generation of massively parallel high-performance computers that will revolutionize the practice of science and engineering.

By Diane Benison

For computer scientists, they are the equivalent of the Holy Grail. They call them the three T's: tips, terabytes and terabps (pronounced terabips). In laymen's terms, they translate to computation speeds in the range of trillions of instructions per second, memories capable of storing trillions of bytes of information, and communications systems that can send information over an optical fiber at the rate of trillions of bits per second.

In each case, the goals are to increase the power of today's best supercomputing systems by a factor of a few hundred to a few thousand. Around the world, a small number of corporate, university and government laboratories are pursuing this dream, hoping to be the first to make machines and systems that meet the challenge of the three T's.

In the United States, these efforts have been bolstered by a major commitment from the federal government, which sees the tera race as a way to help America capture the lead in what may well be one of the most important technological developments of the 1990s. The High-Performance Computing and Communications Initiative (HPCCI), passed by Congress and signed into law by President Bush late last year, will allocate to eight federal agencies—including the Pentagon's Defense Advanced Research Projects Agency (DARPA)—$3 billion over the next five years to fund research and development work in the three Ts.

One of the overriding goals of the push toward tips, terabytes and terabps is the creation of computing technology with which scientists can attack the "grand challenges." A decade ago, Nobel Laureate Kenneth Wilson drew up a list of 10 scientific problems whose solutions will require computing power far in excess of what is now available. In describing the scope of the HPCCI last year, the president's science advisor, D. Allan Bromley, restated these challenges. They include such massive problems as deciphering the human genome, predicting global climate change a century in advance, and taming nuclear fusion.

In a far-reaching move last October, WPI entered the tera race (and in the process, took a giant step into the national spotlight) when its Board of Trustees approved the creation of the Center for High-Performance Computing (CHPC). With the birth of the center, WPI was transformed overnight from a minor player in high-performance computing to a major player, notes WPI President Jon C. Strauss.

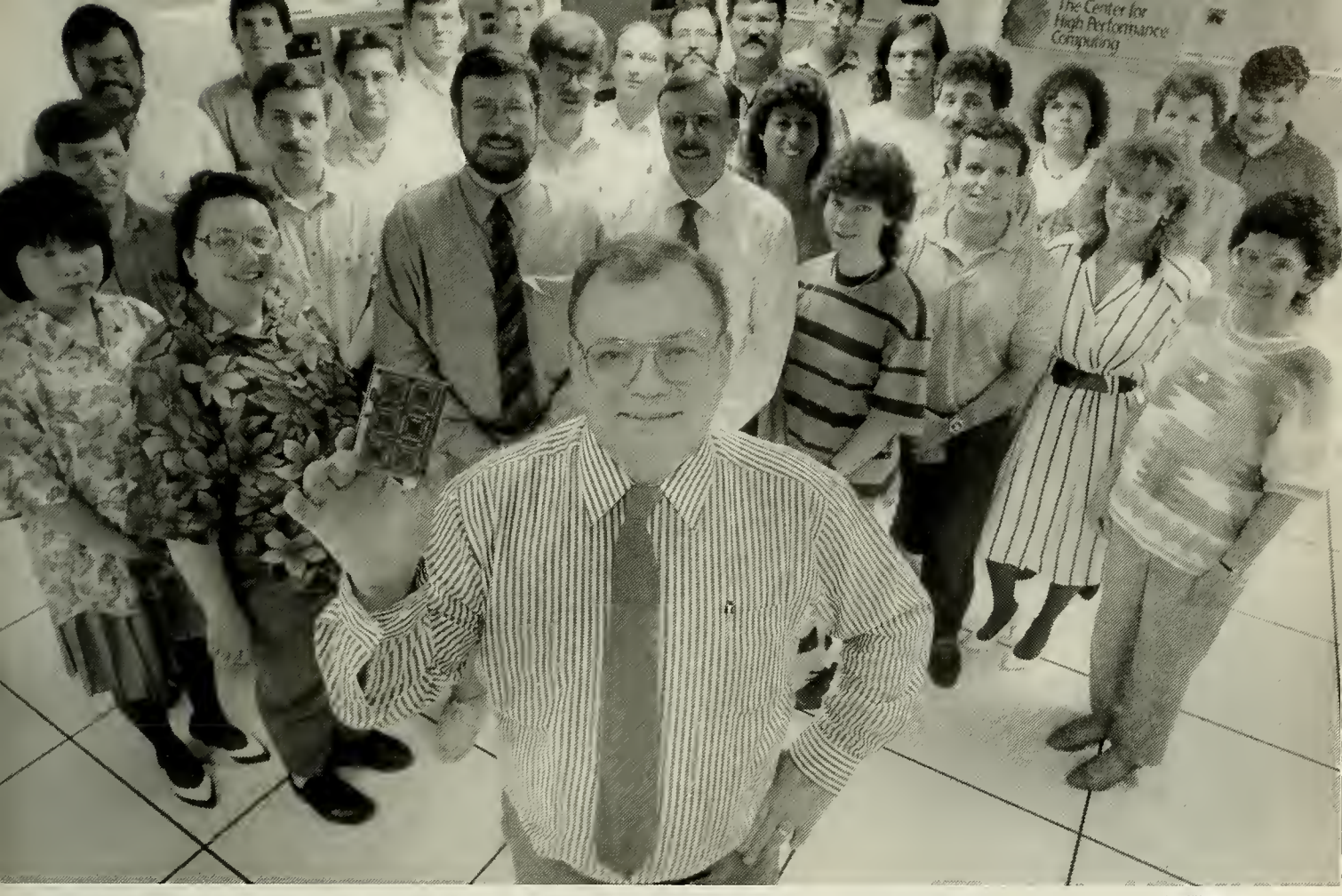
"Launching CHPC was an opportunity for WPI to play a major role in the development of a field of significant importance—not just to this institution, but to our society," Strauss says. "High-performance computation will be one of the keys to improving all aspects of American technology for the next decade and beyond."

Strauss took part in a press conference at the Massachusetts State House on March 4, 1992, during which CHPC was formally announced (the center had been placed in operation earlier in the year). At that press conference, Massachusetts governor William F. Weld said, "The Center for High-Performance Computing is another example of how we've embraced technology transfer in Massachusetts. As the largest center of its kind on the East Coast, it bolsters our national leadership in this important initiative and puts us in a strong position to reap the best developments from federal research."

The center is the "jewel of the East Coast in the technology transfer movement," added Steven Tocco, state economic affairs secretary. "It's a linchpin in our efforts to make sure we don't get devastated by the downturn [in defense spending in Massachusetts]."

CHPC was the brainchild of David Cyganski '75, professor of electrical engineering at WPI, and Thomas A. Probert, the center's founding director. The two began talking about the idea last June when Probert, who was then director of research for Encore Computer Corp., learned that Encore, having acquired the computer division of Gould Computer Systems from Nippon Mining Co. of Japan., was planning to move its research division from Marlboro, Mass., to its headquarters in Ft. Lauderdale, Fla. Probert says the company's high-performance computer research group was reluctant to go. When Encore and the researchers could not reach an agreeable solution, Probert and Cyganski proposed an alliance between the Encore group and WPI.

Prior to Encore's announcement, the company had developed a close working relationship with the Institute, primarily through the efforts of Cyganski and Probert. For example, Cyganski, who in addition to his faculty position was then vice provost and vice president for information systems and services, was involved in WPI's decision to



CHRISTOPHER NAVIN

Holding a prototype of one of the products of the Center for High-Performance Computing, director Thomas A. Probert, center, poses with his staff in the computer room of CHPC headquarters in Marlboro, Mass. The center is developing a new computer system that will process trillions of instructions per second.

purchase three of Encore's multiprocessing computers and communications equipment used throughout the Institute's campuswide computer network. In addition, he and Probert, as liaisons for their respective institutions, had begun to forge links between Encore's research team and researchers at the university.

In their conversations, Cyganski and Probert outlined an arrangement that would enable the Encore research staff to continue its long-standing relationship with DARPA, while at the same time opening the door to further collaborations in high-performance computing between Probert's group and faculty researchers, graduate students and undergraduate project teams at WPI. The result of this brainstorming was CHPC, the Institute's newest multidisciplinary research center.

My idea was that building a functional, self-supporting, academically important, multidisciplinary research center can be a hell of an expensive and risky proposition," Cyganski says. "I thought this would be an interesting test of an altogether different approach—and it has worked. It is self-supporting. And it is contributing to our academic excellence in a variety of ways."

When the proposal to acquire the Encore research group was announced on campus, it received the qualified endorsement of the faculty. (Concerned about the financial risks the center might pose, the faculty requested that those risks be covered from the endowment and not the operating budget.) But at their meeting last fall, the Board of Trustees decided the potential benefits of the center (including increased recognition for the Institute, the enhancement of WPI's research activity, and the boost the center might offer to the recruitment of new faculty members and students) outweighed the risks, and they approved the center unanimously.

Since CHPC has been set up as a cost center, it will derive no operating funds from the university; instead it will be supported entirely by federal and industrial monies. Still, Strauss acknowledges that some of the initial concern about CHPC will likely linger—on and off campus—until the center acquires new federal contracts and until an anticipated growth in nongovernment funding begins to occur.

Funding, in fact, was one of the key concerns as the center was being planned. While he says he was confident DARPA would agree to transfer some of its research monies from Encore to WPI, Probert was relieved last November when the agency announced it was awarding CHPC a $10.6 million contract to develop new high-performance computing technology for the Army and the Navy (see related story, page 15).

The center has already completed a contract from the Open Software Foundation to develop a distributed file

JANET WOODCOCK

David Cyganski, left, and Frederick W. Wheeler '90, who recently received a master's degree in electrical engineering, work on a problem in image recognition. Understanding the benefits that could accrue to WPI from the center, Cyganski helped lay the groundwork for CHPC and became its major advocate on campus.

server for its Mach operating system. The contract is part of a larger project to develop a real-time version of the operating system for parallel processing computers. In addition, the center will be seeking funds from other government agencies, including the National Science Foundation and the departments of Commerce and Energy.

Strauss says WPI would not have received the DARPA funding without the Encore group, but Probert credits the combination of his group's previous work with DARPA and the university's unique educational program for securing that first contract. Prior to receiving the grant, he notes, Cyganski gave a briefing on the WPI Plan, the Institute's project-based undergraduate curriculum, to DARPA officials, who seemed intrigued by this innovative educational model.

When WPI created CHPC, it hired as regular, full-time employees the 25 professionals and five support staff members who constituted the Encore research team. The university decided to locate these new employees in Marlboro, about 14 miles to the east of Worcester, because of a lack of adequate space on campus and because most of the CHPC staff live between Marlboro and Boston.

Its location and the makeup of its staff (predominantly full-time professionals, rather than faculty members and graduate students) are not the only characteristics that distinguish CHPC from WPI's other multidisciplinary research centers; the center will also operate according to a different model. Probert says CHPC is committed to taking the knowledge and technology it develops in the course of its work and transferring it rapidly into commercial use.

"Our purpose is to transfer technology," he says firmly when asked to define his vision of the new center. Speaking with the animation of a man with a mission, he says he sees CHPC as a change agent, transferring technology out of the lab, out of the classroom, out of the world of academic publication, and into prototypes for products that will then be taken to market and supported by industry.

Probert, who became familiar with this process as a principal scientist at MITRE Corp., as a consultant to the deputy undersecretary of defense for research and engineering, and as a founding director of the Computer and Software Engineering Division of the Institute for Defense Analysis, says it currently takes far too long for technological research and development to make its way into commercial use.

"I spent 10 years in the Department of Defense working with 'Beltway bandits' and aerospace contractors," he notes. "I saw some pretty neat stuff being invented and developed within university and research labs, and then saw it sit on the shelf because

it was too advanced, because there was no market for it at the time, or because it was just thrown over the transom for the development guys to do something with. The development guys would say, 'We don't understand this; it wasn't invented here.' Then they'd go and reinvent the wheel.

"I did a series of studies at DOD looking at how technology is moved from R&D and into industrial practice. In the U.S. it can take 15 years from the time something is first published to the time 40 percent of it shows up adopted in industry. It's true across disciplines. And it's largely a people problem." Probert says the same process takes about eight years in Japan, a target he'd like to aim for at CHPC.

Part of the problem, Probert says, is a difference in the way the two nations view base technologies. Japanese manufacturers, he says, regard base technologies like new multiprocessing architectures as sharable; only the specific products that grow out of those technologies are jealously guarded. In America, antitrust laws, regulations and corporate suspiciousness make sharing base technologies difficult. Therefore, competing companies must each go through the time-consuming and costly process of inventing these technologies on their own.

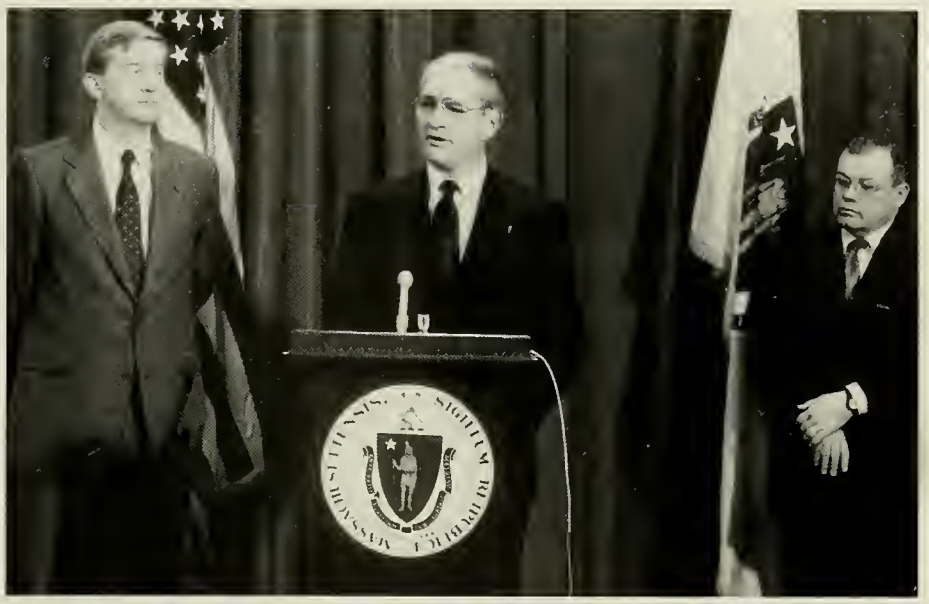
Probert says the CHPC model, which calls for getting industry directly involved in the center, is designed to overcome some of these obstacles to technology transfer. Individuals and corporations can join CHPC in a number of ways (see box), each of which carries with it a different level of financial and personal commitment and a different set of benefits.

The highest level of involvement is sponsorship, which corporations can earn with an annual fee of $48,000. The fee entitles sponsoring companies to bring their own technology problems to the center for consulting help. It also enables them to set up bridge programs to transfer technology prototypes developed at CHPC into early versions of actual products—called beta versions—that can then be tested in the field.

Not unlike the Japanese model, the center's base technology—much of it developed with the support of government agencies that want to see this new technology put to widespread use—will be available to all sponsors, while the details of specific bridge contracts will be carefully guarded.

Money alone, however, will not get a company into a bridge program. Bridge participants must send two high-level employees to work with the CHPC staff as the technology makes its way from research lab to test site. Probert says he sees this as critical to the success of the transfer process.

Making the bridge program even more attractive is the fact that CHPC will charge no licensing fees for the technology it develops under government contracts. Sponsors will be able to make use of the technology at no charge, with the proviso that they pay royalties to the center on any product that results from it. But it is the collaboration between co-located employees and CHPC staff that will truly be the key to the successful transfer of technology, Probert notes.



JOHN CHOMITZ

WPI President Jon C. Strauss, center, speaks to reporters at a State House press conference held earlier this year to announce the formation of CHPC. Massachusetts Governor William F. Weld, left, and CHPC director Thomas A. Probert look on.

"Technology does not move through diagrams and patents, through formulas or specifications, through literature, or even through prototypes," he says. "Technology moves through people. So you put people together and they develop credibility with each other, and then they actively transfer the technology.

"We're going to show them how to take the things we know how to do and translate them into products. Then they'll go away and build those products. We may build them the beta versions, but they'll build the final products—and they'll sell and support them. But this is the magic: they won't walk away with just a thing; they'll have an understanding that will allow them to modify the technology, to further it, and to extend it to meet their particular product dimension."

In attracting potential sponsors, Probert says the experience of his research and development team has been a plus. That experience includes the successful development of a number of hardware and software products for Encore, including a version of Mach for Encore's parallel processing computers; the first parallel implementation of Ada, the programming language used by the defense department; and a small-scale version of GigaMax, an early attempt at a massively parallel computer.

That experience can save sponsors from making costly mistakes, as one company (now a sponsor) found out when it visited the center. "They were trying to build an aggressively packaged processing module and put it on a board," Probert says. "We said, 'Don't do that. We tried it and found that the board will delaminate if you use that bonding technology.' They immediately saved $850,000 by moving the project in a different direction."

Because building technology bridges is as much a process of education as it is of research and development, Probert says it was a natural move to associate his research group with a university. Strauss says he agrees, adding that the goal of the center—finding real-world applications for leading-edge research—is a particularly good fit with WPI's "Two Towers" tradition of combining the academic and the practical (a philosophy captured in the Institute's motto, "Lehr und Kunst," which is usually translated as learning and the skilled arts).

Strauss says he is as enthusiastic about CHPC as Probert, but for different reasons. While Probert is excited about the possibility of changing the way and the speed with which industry incorporates new computing technology, Strauss sees a strong relationship developing between CHPC's research directions and the interests of WPI's Computer Science and Electrical and Computer Engineering departments.

"I hope some of our regular faculty members will become engaged—either as consultants or as staff—in some of the ongoing

Building Bridges: How to Get Involved in CHPC

One of the primary goals of the Center for High-Performance Computing, according to its founder, Thomas A. Probert, is getting new developments in computer technology incorporated into actual products as quickly as possible. To meet that goal, the center has invited individuals and American high-technology companies to become directly involved in the center.

Currently, CHPC offers four levels of involvement, each of which provides different advantages, and each of which has a different cost associated with it. Here is a quick look at how individuals and companies can join the technology transfer process:

Membership: This is intended for individuals. It is the least expensive level and entitles one to receive a periodic newsletter from the center that reviews its research and technology developments. Members may also attend an annual symposium on high-performance computing sponsored by the center.

Cost: $350 per year

Associate: This level is aimed at companies. In addition to the benefits of membership, it offers access to the center's in-depth analysis and technical reports. The reports focus on specific topics and contain information on what the CHPC R&D team has found—through its own experience and its industry contacts—to actually work.

Cost: $9,500 per year

Sponsorship: This level is also aimed at companies. It includes the benefits of the associate level, plus consulting by the center staff to address technology issues on a time-and-materials basis.

Cost: $48,000 per year

Technology Transfer Programs: These are sponsor-specific bridge programs aimed at getting core technology incorporated quickly into a sponsor's products.

Cost: Negotiated individually on basis of scope of project

Currently, the emphasis is on signing up sponsors and developing technology transfer programs. By early summer, CHPC had four sponsors: Encore Computer Corp., Mercury Computer Systems Co., Data General Corp. and the Open Software Foundation (OSF). Some of these members have also provided the center with equipment. For example, Data General has leased to CHPC $750,000 worth of its new Aviion computers at a substantial discount. In return, the center will develop a version of the OSF Mach operating system to run on the Aviion.

Probert says he expects the center to have 20 sponsors by the end of its first full year of operation. Long-term plans call for the center to sign an unlimited number of members, 200 associates and 75 sponsors. He says he also expects that the center will ultimately be able to handle about 10 bridge contracts at any one time. To date, two bridge contracts have been completed and a third is anticipated.

CHPC work, be it hardware or software development," he says. "I would expect that some of our graduate students would be supported as research assistants through CHPC and that more and more of our undergraduates would do their Major Qualifying Projects as part of the CHPC's work.

"In addition, I would expect that we will draw more and more on the CHPC professional staff to serve as adjunct faculty members, teaching courses and possibly some special professional seminars under the auspices of WPI. Several staff members are Ph.D.-trained and fully qualified to accept faculty appointments."

One of those is Probert, who earned his master's and doctoral degrees in computer and information science at the University of Massachusetts after completing graduate work in biology at Northeastern University. In fact, he served as an adjunct professor at WPI in the 1970s and says he may be back in the classroom early next year.

Cyganski says Strauss' hopes are already being realized. "We now have a constant pump of high-technology information into our educational program," he notes. "We have members of the center's staff giving lectures and co-teaching courses. We have graduate students completing theses working hand-in-hand with WPI faculty and CHPC staff. We have several proposals for further academic research that have been co-authored by researchers from the Institute and the center. I can't believe how much has happened in just a few months."

Strauss says he sees other benefits accruing to WPI from the creation and success of CHPC. In particular, he says the center's DARPA funding and its ability to attract federal and industrial sponsors for itself and for other WPI programs will enhance WPI's own reputation and credibility among these funding sources.

"I was a strong proponent of establishing this operation," he says. "But I'm more exposed on this than I am on most projects, because generally in my role as facilitator, I'm promoting an existing faculty member who is taking on or developing a new enterprise. In this instance, we brought in a tailor-made enterprise and assumed more risk than the majority of our faculty was comfortable with. We could not have done that without the strong support of Dave Cyganski and others who have significant credibility—well earned and well deserved—with their faculty colleagues."

Strauss says he hopes alumni and the rest of the WPI community will share his vision. "This is an exciting venture that has excellent promise of success—success that will be to the benefit of WPI on both the academic and the recognition fronts," he says. "I'd like our folks to be excited about the possibility of making a difference in an important area. The grand challenges of computation are all means to an end. The end, of course, is the computational ability that will enable us to do better science and to learn more about our world."

Probert echoes Strauss' hopes. "I want to be in the situation of MIT's Draper Labs," he says. "Draper turns down hundreds of millions of dollars of research work and contract work every year. They do that based on the fact that they're full up; they can't take any more.

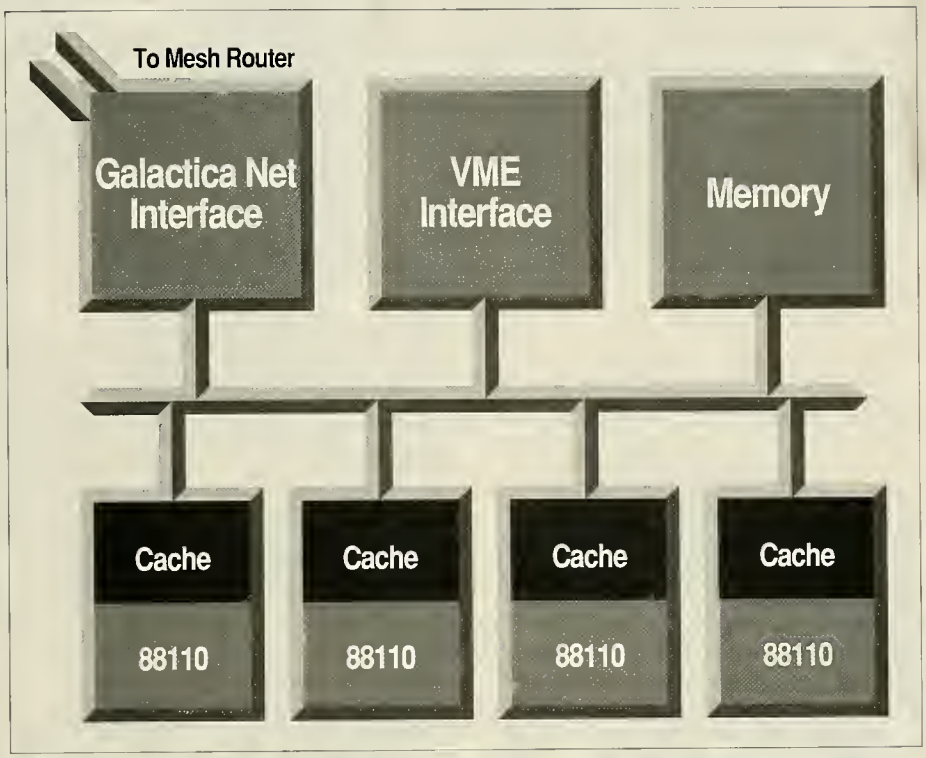
"But there's not a single military radar project in the country that doesn't go through Draper Labs. Draper is the place to go to understand radar. You cannot get a project funded, and it will be questioned in Congress and in the military, unless you have a Draper guy look at it. That gives you an idea of their reputation. We want that reputation for CHPC."

A former newspaper editor, Diane Benison is now a free-lance writer and editor who also teaches journalism in Clark University's College of Professional and Continuing Education.

DIVIDE AND CONQUER

The secret to building computers that can handle trillions of instructions per second lies in splitting problems into pieces and solving them simultaneously on hundreds—or even hundreds of thousands—of individual processors. Here's an introduction to the brave new world of high-performance computing.

BY MICHAEL DORSEY



ILLUSTRATIONS COURTESY OF ESTRELA OESIGN

The Lynx node being developed by the Center for High-Performance Computing consists of four powerful Motorola 88110 processors with their own memory caches, 256 million bytes of memory and devices that will connect the module to a fiber-optic network.

In 1959 WPI purchased one of its first digital computers, an IBM 610 Autopoint. Running at peak speed the machine could execute a few thousand instructions each second. Over the next few decades, computer speeds increased dramatically. By 1980, when the Institute acquired a Digital Equipment Corp. DEC-20, mainframes were routinely cranking through programs at the astounding rate of a million instructions per second (mips), or about 1,000 times as fast as the IBM 610.

Today, just over a decade later, the stage is being set for a million-fold jump in speed over computers like the DEC-20. The latest generation of supercomputers are already processing billions of instructions per second (bips), and a growing number of high-tech companies are setting their sights on the trillions of instructions per second (tips) mark. (Last fall, Cambridge-based Thinking Machines Inc. announced it had crossed that magic boundary in the laboratory with its newest Connection Machine.)

How fast is a trillion instructions per second? Think about it this way: An excellent typist may tap out about 75 words a minute. If the average word is about six characters long, that amounts to 450 characters per minute or 7.5 individual keystrokes—just over one word—a second. In one second the IBM 610 could have processed at least 1,000 characters, or about the number of words on two-thirds of a double-spaced typewritten page.

In one second the DEC-20 would have gone through a million characters, or about the number of words in two 250-page novels. By contrast, a one-tips computer could race through a trillion characters in that same second. That's like typing all of the words in 2,000 novels in the blink of an eye. The increase in computing speed achieved over the past three decades is akin to taking a jet that can fly 1,000 miles an hour and turning it into a starship that can travel 1,500 times the speed of light.

Reaching for the tips prize has required a new approach to computing. Traditionally, a computer has consisted of a single processor, some form of storage or memory, and various input and output devices like keyboards and printers. Like a lone typist who completes a manuscript one character at a time, a single-processor computer plods through programs in serial fashion—one instruction at a time.

To make computers faster, designers have turned to faster processors and have found ways to pack components closer together on integrated circuits to shorten the distance electrons must travel as they whiz around these chips (see illustration, pages 16 to 17). But designers who follow this approach ultimately run up against barriers caused by the physical limitations inherent in the materials they use to make computer chips. Even exotic substances like gallium arsenide, which may be used in the next generation of supercomputers, have inherent speed limits.

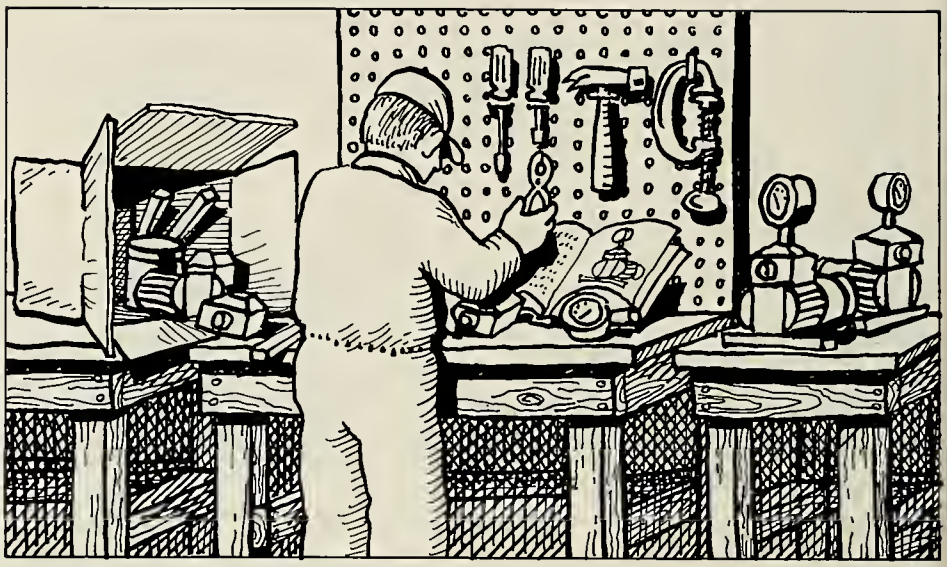
But there is another avenue to greater speed. Just as one can get a 10-chapter book typed 10 times more quickly by giving each chapter to a different typist, a computer can work through a computer program much faster if the program is first split into pieces, each of which can then run on a separate processor. This technique, called multiprocessing or parallel computing, is the

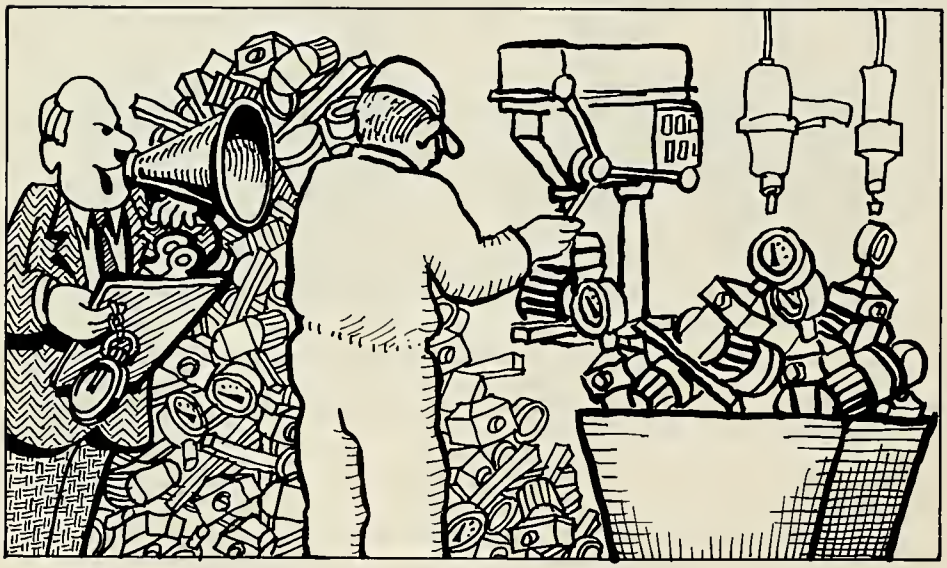
(Continued on page 18)

The Road to the Tips Machine...

1 Computing in a Straight Line

Traditionally, computers have performed tasks in a serial or step-by-step fashion, the way an individual craftsman builds a product. In these machines, which include most personal computers and mainframes, a single processor carries out one instruction at a time.



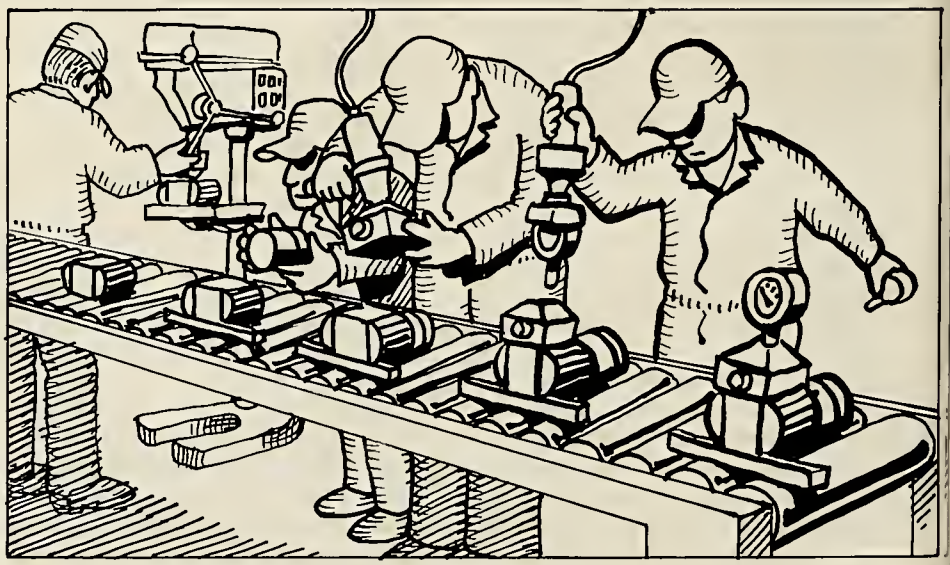


2 Faster, Faster, Faster

The first supercomputers achieved high speeds by accelerating the computer's internal clock, making the processor race through instructions at a faster pace. This was accomplished by building smaller, faster circuits that could process information much more quickly. Some designers have experimented with still-faster materials, such as gallium arsenide, but so far these have proved difficult to work with and are less reliable than the silicon traditionally used in computer chips.

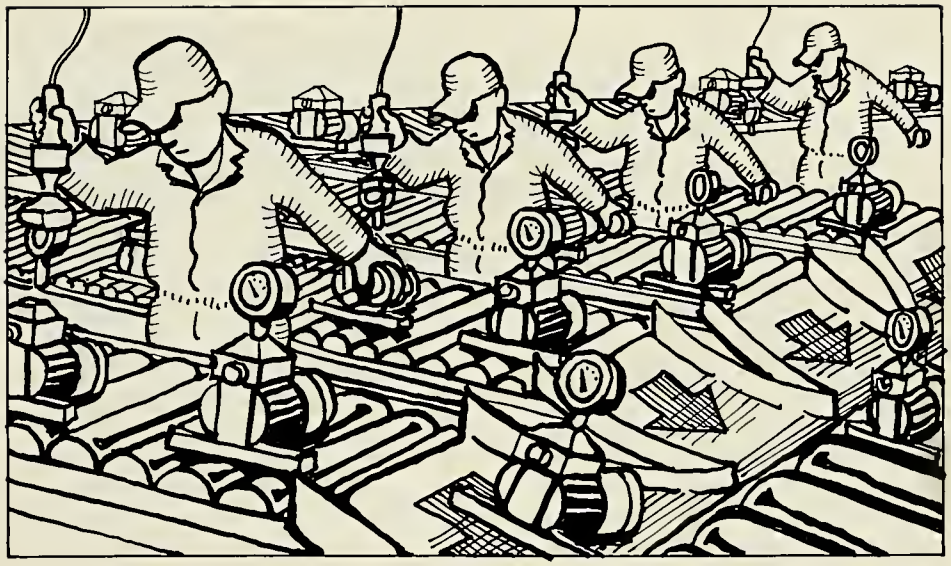
3 Racing Down the Pipeline

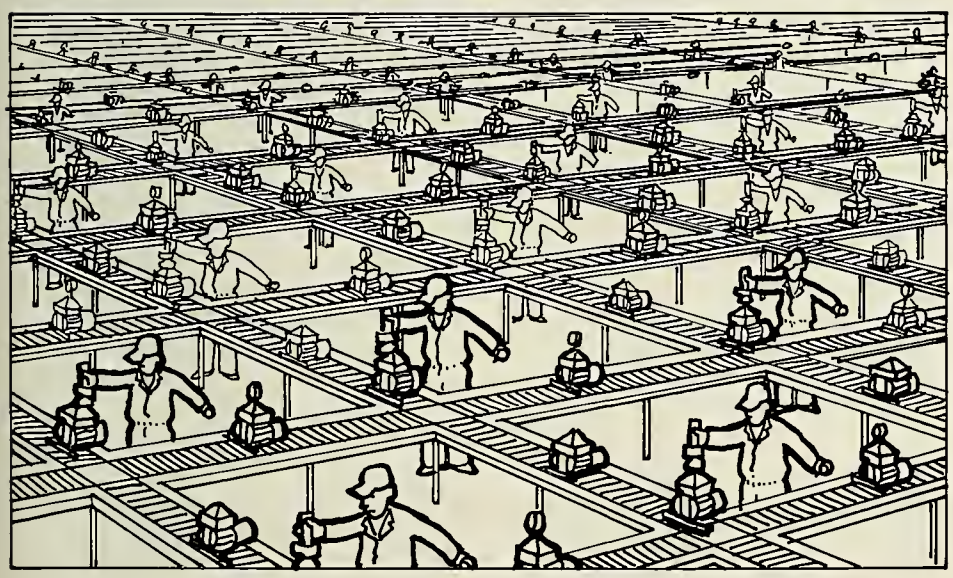
There are physical limitations to how fast one can make components or how closely one can pack them together. To add more speed, some supercomputer designers split the central processor into subprocessors, each of which carries out just part of an instruction—much like workers on an assembly line each do one part of a task. As the second subprocessor does its job, the first can be starting on the next instruction and so on, saving time.



4 Vectoring for Speed

Many supercomputers use a vectored architecture in which several subprocessors simultaneously perform the exact same operation on every number in an array of data, called a vector. Today the dominant supercomputer design is several vector processors linked together. These machines generally run at the low end of the bips range (that's billions of instructions per second).



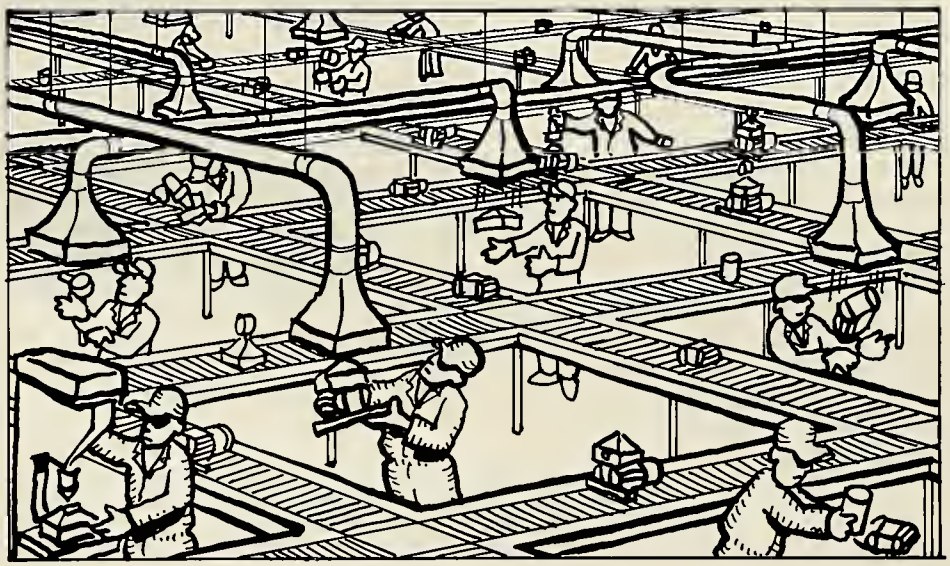


5 In Numbers There is Speed

The latest trend in supercomputing is called the massively parallel machine, in which problems are broken up into many pieces and run on hundreds or even thousands of processors. Some of these designs operate on the principle of single-instruction, multiple-data (SIMD—pronounced sim-dee), in which each active processor is always performing the same task as every other processor. To reach the tips range—trillions of instructions per second—SIMD computers require many thousands of processors.

6 Processors With Minds of Their Own

The other approach in massively parallel computers is the multiple-instruction, multiple data (MIMD, or mim-dee) mode, in which a smaller number of processors work independently, performing different operations on different pieces of data. The major challenge in using either SIMD or MIMD machines is writing programs that effectively break down problems to take advantage of the speed inherent in having many, many processors working as a team.



(Continued from page 15)

one most designers of high-performance machines are turning to.

There are two basic approaches to multiprocessing. The first is called single instruction, multiple data or SIMD (pronounced sim-dee). In SIMD machines the processors behave like galley slaves, each performing the exact same operation at the same time on different bits of data. In an image processing application, for example, one might want to quickly change the color of every picture element in a television image. With a SIMD computer, you'd assign one processor to each element, allowing the computer to accomplish the changeover in one step (on a single-processor machine, in contrast, the changeover would take as many steps as there are picture elements).

SIMD computers derive their speed from sheer numbers, rather than from the power of the individual processors (one Connection Machine currently on the market employs 128,000 processors). But to use this computing horsepower, one needs a problem that can be broken into many essentially identical pieces. But most scientific and engineering problems require a more flexible approach. That's why most multiprocessor computers are MIMD or multiple instruction, multiple data machines.

In a MIMD computer, a problem is broken into units that are assigned to a comparatively small number of powerful processors. Unlike the galley-slave synchronization of SIMD machines, each processor in a MIMD architecture can perform a different operation on the data in its memory and can proceed at its own pace.

"MIMD is far more powerful and far more general than SIMD," notes Thomas A. Probert, director of WPI's Center for High-Performance Computing (CHPC), who says that MIMD is the path CHPC is following. Currently, engineers at the center are developing a MIMD processor called Lynx as part of a $10.6 million contract with the Defense Advanced Research Projects Agency (DARPA). Each Lynx unit or node will consist of four Motorola 88110 microprocessors joined by a fiber-optic bus. These extremely fast (50 megahertz), reduced-instruction-set-computing (RISC) processors, along with 256 million bytes of memory and an interface device, will fit in a box about the size of a slide projector.

By itself, Lynx would make an impressive small supercomputer. At a normal operating speed of 200 million instructions per second (that's the equivalent of 200 DEC-20s), it is faster than many machines currently on the market. But what makes it a contender in the tips race is its scalability. Put two Lynx nodes together and you double their speed; add 98 more, and you've got a computer operating at nearly 20 billion instructions per second. In theory, there is no limit (other than price) on the number of Lynx nodes that can be joined into a single computer.

"We've simulated up to 2,000 interconnected Lynx nodes," Probert says. "We've taken actual instruction traces from serial computers and fed them through the simulation, validating that the program does the right memory references and so on. We know it will work."

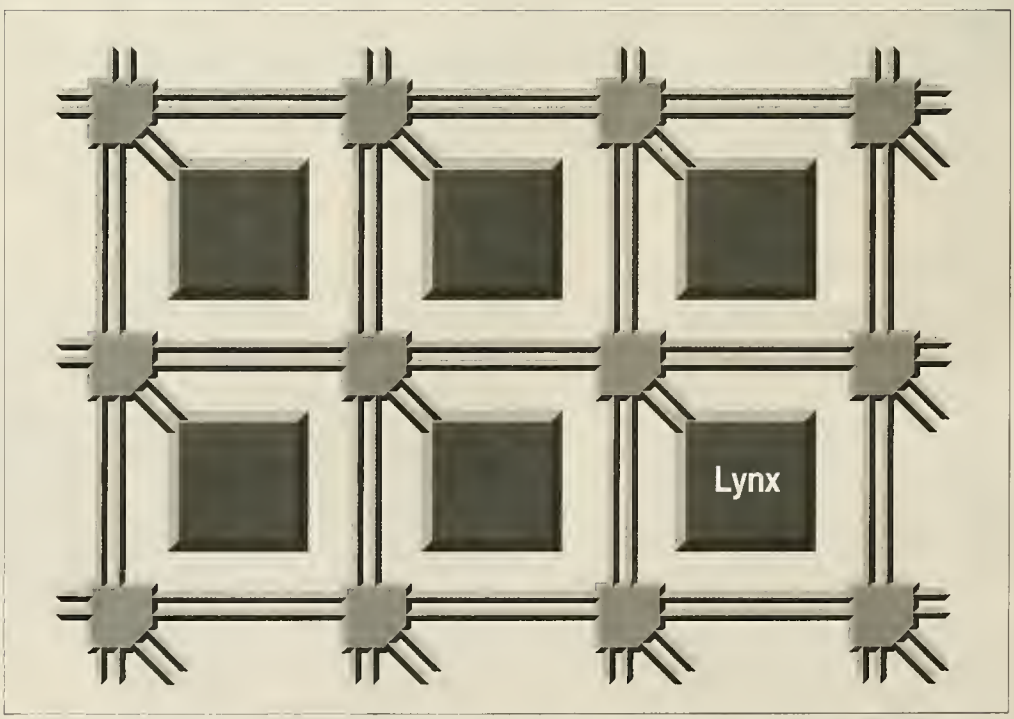
The Lynx processors can be hooked together by Galactica Net, a unique two-dimensional fiber-optic highway that can move data about at the rate of a million bits of information per second. Each processor is connected to a device called a router that, in turn, is linked to four other routers and so on. Galactica Net connects the processors to each other and to a shared memory.

While it can be slower than some other connection schemes used in multicomputers, Probert says the simple mesh has two important advantages. First, it is easier to scale up a mesh into the type of massively parallel machine needed to reach the tips benchmark. And second, because the connections between the processors and the mesh are fairly simple, there is no need for the specialized hardware that must be designed for some architectures—including the popular hypercube, which places the processors at the corners of a multidimensional cube.

Galactica Net is a distributed, shared-memory architecture, which means that all of the Lynx processors make use of the same distributed, shared memory. To minimize what is known as data contention, which occurs when several processors try to manipulate the same piece of data at the same time, Probert says the CHPC designers have given each processor its own memory cache.

When several processors need the same data, each writes the information to its own cache. Only one processor can change the data; the others check to see whether they might need to alter it. When the first processor is finished updating the data, it writes the new value into the caches of the other processors and into the shared memory. Another processor then gets the go ahead to change the data, and the process continues.

Probert says CHPC has filed for a patent on the memory protocol and also has a patent pending on Galactica Net and the software that drives it. He notes that the center has deliberately placed much of the complexity of its multicomputer into this software, rather than into the hardware itself, even though the latter approach often results in a boost in operating speed. He



Hundreds of Lynx nodes can be joined together by Galactica Net, a mesh-like fiber-optic network. Each Lynx node is connected to a router, which, in turn, is linked to four other routers. The routers connect the processors to each other and to a large shared, distributed memory.

> *"We've simulated up to 2,000 interconnected Lynx nodes. We've taken actual instruction traces from serial computers and fed them through the simulation, validating that the program does the right memory references and so on. We know it will work."*
>
> —THOMAS PROBERT

says the CHPC team has learned the value of this approach through experience.

When CHPC's 25 engineers and designers constituted Encore Computer Corp.'s high-performance computer design group, they worked on a project called GigaMax under an earlier DARPA contract. The goal was to develop a bips computer, but the project became bogged down by the difficulty of designing and building hugely complex circuit boards. "We learned that attempting to place all the complexity in the hardware to gain speed leads to problems," he notes.

"We had to build 14-inch-by-17-inch computer boards that were 14-layers thick and that had components mounted on both sides. The state of the art in layout tools couldn't handle the complexity of those boards, so we had to do a lot of the layout by hand. It was almost impossible to implement. Now we've moved a lot of that complexity into the software, which is far more flexible and much easier to modify."

That does not mean that Lynx is not complex, Probert says. In fact, the sheer intricateness of the processor is the primary reason it exists now only in their minds and in computer simulators. "When you have things that are operating at 100 mips or more, you have to anticipate every single possibility," he notes.

"That's where people fail. You just can't forget one condition. Since the programs execute so quickly, you can guarantee that almost every path through a circuit will be used at least once. If you've forgotten something, you'll fail. And once you've built the thing, it's almost impossible to find where the problem is. With a parallel machine, a program might run differently each time through, and a bug may not show up every time you run it."

Such seemingly random variations in the way the same program may run on the same machine is just one of the qualities of multicomputers that make programing them more challenging than writing instructions for serial computers, Probert says. To help users deal with these complexities, CHPC is developing a powerful suite of programming tools called Insight. One of the unique features of Insight is its ability to give a multicomputer a sort of introspective quality.

"Insight enables one set of processors—through memory—to watch another set," Probert says. "The advantage is that it is nonintrusive; it does not obstruct the instruction stream. No one else has anything like this. It's unique in the industry."

Probert says using Insight is like placing a glass window over the computer and watching how it goes about executing a program. To use the tool, a user installs small programs called observers. The observers attach themselves to specific locations in the computer's memory and keep track of all the operations that use those locations. By providing feedback on potential problems with a program and by pinpointing ways the program may not be using the computer efficiently, Insight will help users write effective application software without having to be intimately familiar with the workings of the computer.

Insight should help third-party software developers create libraries of application software for parallel computing, something that has not happened yet because of the limited marketplace for multicomputers (they currently account for just one-tenth of one percent of all computer systems in the U.S.) "Parallel processors are not available because the broad exposure is not there yet," Probert says. "Without the machines, application programmers don't write programs for parallel machines. Without the programs, people don't buy the machines."

Probert says university programs like CHPC may play a role in breaking this circle by giving students access to parallel computing and encouraging them to explore its possibilities. He says the advent of personal computers with multiple processors—which should be on the market around the middle of the decade—may also help shift the balance toward parallel computing.

As that shift takes place, Probert says myriad applications should open up for multicomputers. Many will be in science, where massive problems like studying changes in ecosystems or predicting the weather require the manipulation of massive amounts of data. But, he notes, there are many other applications in manufacturing, biotechnology, business and other fields that can use the speed and power of parallel computing. Eventually, he predicts, all computers will be parallel.

Many of these applications will have to operate in real-time, with the computer working fast enough to respond to events as they happen. Probert, David Cyganski, professor of electrical engineering, and John A. Orr, professor and head of the Electrical and Computer Engineering Department, are anticipating a grant from DARPA that will fund the development of a three-dimensional user interface that, when integrated to Lynx and Galactica Net, will enable users to manipulate satellite images in real time.

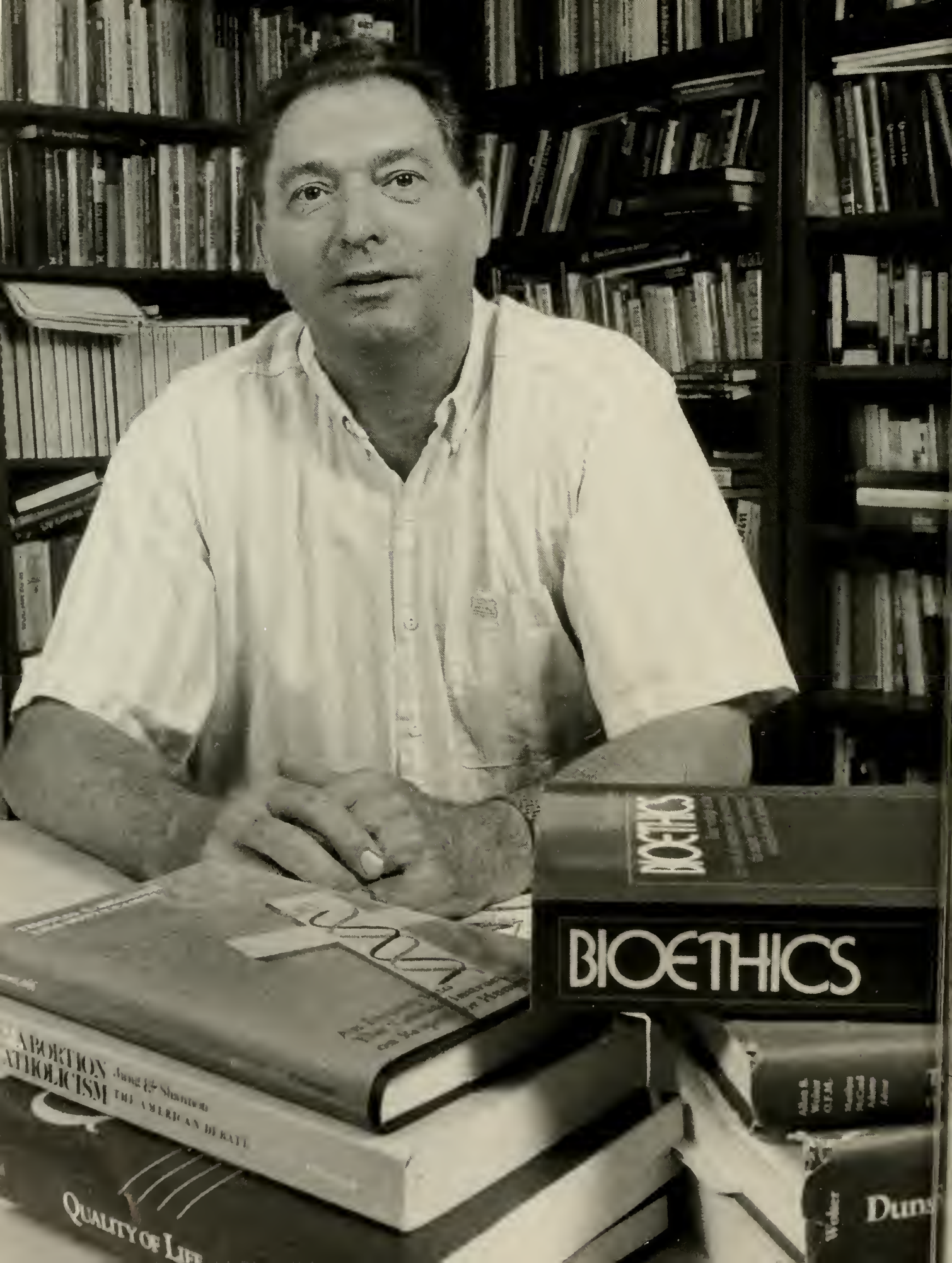
Called Visual Lynx, the system will display a three-dimensional representation of a picture as it is beamed down from the satellite. The user, whether a military analyst in Washington or a fisheries biologist out at sea, will be able to indicate a section of the image he'd like to view in more detail and direct the satellite to zoom in on it or employ a different sensor to study it.

"You've got a satellite up there and it's moving at 18,000 miles an hour and taking a picture," Probert says. "If it takes too long to do the processing and send the command, by the time the signal gets back up there the sensors will be pointing at something else. This is different from the traditional supercomputer application, in which someone goes off and runs a program that might compute for minutes or even hours."

While Visual Lynx will take a few years to develop, the first working prototype of the Lynx-Galactica Net system should be up and running in January 1993, Probert says. "We won't lay anything out before November. Now it's all staging, design, simulation and so on. Once it's built, it's built. We won't change it. That's why we'll do as much as we possibly can before we get to that stage."

While this new multicomputing architecture will be available to CHPC's sponsors—and will, most likely, end up being transferred to many real products—Probert says the first "customer" for the system will be the federal government, which will decide whether Lynx or one of a few other "shadow technologies" being funded by DARPA will be adopted as a primary high-performance computing platform for the U.S. Navy. "If we're successful, this technology could be inserted into a major program. This is the kind of thing that makes companies. The stakes are high, as are the risks, but the payoff could be very high indeed."

Reporting by Diane Benison contributed to this article.


BIOETHICS
QUALITY OF LIFE

First, Do No Harm

More than two thousand years ago, Hippocrates set forth that simple rule for physicians. But as modern technology has transformed the practice of medicine, enabling doctors to postpone death and manipulate the genetic code that is the root of human life, the line between healing and harming has been blurred. As professor of religion and social ethics, Thomas Shannon works to bring the ethical issues of modern medicine into sharp focus.

By Diane Benison

"I observe the physician with the same diligence as he the disease."

—*John Donne*

I'm not against technology. I'm not against its proper use. What bothers me is its improper use, or its overuse," Thomas A. Shannon says. Shannon, a bioethicist, has spent his adult life thinking and writing about the appropriate use of technology in health care, a topic he also focuses on in the classroom with his students at WPI.

Because his expertise is recognized nationally, mainstream media call him occasionally for comment when the use of medical technology becomes news. But he's not likely to make the Oprah-Donahue-Povich circuit anytime soon. His story about being a guest on a 1977 David Suskind Show on euthanasia explains why.

"They interviewed me in advance over the phone," he remembers. "At one point the staff person said, 'You know, you're really too mild. Can't you take one extreme or the other?'" Shannon says he was startled. He'd been trying to identify the issues, methodically examine the underlying values, and then weigh those values against one another. "They didn't want that," he says. "They wanted entertainment."

Shannon is thought-provoking, a quality not often thought of as entertaining by the electronic media. But if the standing-room-only crowd of alumni at Reunion in early June was any indication, Shannon is worth listening to. They sat and stood with focused attention during his 50-minute presentation. When his talk about ethics and health care ended, he spent another 15 minutes with the small group that stayed behind to ask questions.

Shannon, professor of religion and social ethics in WPI's Humanities Department, has published his ethical arguments on a wide range of issues—including bioethics, theology, and peace and war—in the 15 books he has authored or edited and in 25 articles in scholarly and mainstream publications. He has also delivered more than 40 presentations at professional meetings.

Among the honors he has earned at WPI for his scholarship and teaching are the Paris Fletcher Distinguished Professorship in the Humanities, which he currently holds, and the 1988 Trustees' Award for Outstanding Creative Scholarship.

In his writings, Shannon advocates the adoption and use of medical technology within the context of meeting human needs. Those needs, he emphasizes, are not just biological, but may be emotional, psychological and spiritual, as well. More and more, though, as technology has come to drive medical decisions, a patient's biological needs are the only ones that are considered and valued, Shannon says. When that happens, the emphasis of the medical profession shifts from caring to curing, which may not be appropriate in all cases.

Shannon says he believes the unintended consequence of technology-centered medicine is materialistic, reductionist thinking that

sees people as merely means to an end. He says this outcome was evident recently in the much-publicized case of a couple who conceived a child because they needed a compatible bone marrow donor for a daughter with leukemia. But more than anything, Shannon says, it is the neglect or disregard of those other human needs that concerns him.

Though they are much more complicated, divisive and publicly discussed today, the primary ethical issues surrounding modern medical technology and its use are "the same ones that have been around since the early days of bioethics about 25 years ago," Shannon says. "Abortion, euthanasia, genetic screening, organ transplantation, the definition of death, informed consent, research on human subjects—it's the standard list."

Despite two and a half decades of discussion, Shannon says these issues are not any better resolved today than they were when he received his Ph.D. from the division of theological and religious studies at Boston University in 1973 (he also holds a bachelor of arts degree from Quincy College in Quincy, Ill., a bachelor's of sacred theology from St. Joseph Seminary in Teutopolis, Ill., and a master's of sacred theology from the Boston University School of Theology).

"I think the positions are staked out better. What's changing is the social policy and the social practice—and we're not getting much more unity of desire for legislation," he says, though he adds that legislation on such complex issues is not always a good idea, as laws—which are often too specific or too vague—can undercut privacy, personal autonomy and the medical doctrine of informed consent.

A realist, Shannon says he doesn't expect to see the resolution of any of the ethical issues raised by the use of medical technology anytime soon. "One thing that's remained constant over the last two decades is that technology continues to outpace ethics and the law," he says. "I think that's partly cultural, because in our country we take the position that nothing can be stopped. Instead, we implement technology as soon as it's available.

"When problems do arise, we have to stop and say, 'Oh, now what are we going to do about this?' Then we try to regulate something that is already in motion, something that people are already using, and something that people claim they have a right to—even though it may be really problematic."

In a sense, many of the ethical problems in medicine can be traced to the great success the medical profession has had in recent decades in developing new forms of treatment and disease prevention, Shannon says. As new ways of diagnosing and curing illnesses—things like CAT and MRI scanners, nuclear medicine and heart transplants—have entered the mainstream, physicians and patients alike have continued to look for even more powerful and exotic technologies.

But placing new medical devices and procedures into service too quickly can be risky, Shannon says, because it is often difficult to anticipate the ultimate effects of a new technology. He cites the invention of the automobile as an example of a machine that has had broad and unintended consequences, impacting both social patterns and the environment. Shannon says he doubts Henry Ford considered these implications when he started building cars.

One of the general effects of new and more elaborate medical technology has been the rising cost of health care, Shannon notes. "Now the major problem is often not that we can't cure, but that when we do it requires ever more money and time."

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Shannon says he is not eager to belittle the advances of medical technology. But he says he believes the tendency of physicians today to pay attention to data instead of to patients' feelings is a problem inherent in that technology. "High-tech medicine is better at treating individual organs than individuals as a whole," he says.

The phenomenon of "medical options that quickly become obligations" (as when hospitals feel they must always use intravenous feeding, resuscitators and defibrillators to keep critically ill patients alive) is another consequence of modern medical technology, Shannon says. When the obligatory use of such technology results in highly visible cases of persistent vegetative state (PVS)—like those of Karen Ann Quinlan and Nancy Cruzan—people become worried about getting trapped by the technology.

That, Shannon worries, may cause some people to reject potentially helpful treatments, because they believe they won't be allowed to stop treatment once it has been started. He says he believes this fear of being trapped by high-tech medicine has helped drive the euthanasia movement, and also ignited interest in living wills and durable powers of attorney.

The fear of being held hostage to modern medicine is a consequence of our inability to distinguish between caring and treating, Shannon says. "We have the sense that if we stop treating, we've stopped caring. That's a bad distinction. In some cases people simply cannot be cured, but we certainly can still care as they go through their illness. But our culture is bad at this. We'd like to turn it over to someone else—or to technology. You get the sense that the only thing that can stop treatment sometimes is a cosmic power failure—like the Northeast blackout—and that's awful to think about."

Shannon says he is equally concerned about how that same technological imperative (a medical option becoming an obligation) has insidiously impacted our thinking about organ transplantation—with even broader social consequences. Constant advances in the technology of organ transplantation—and the resulting growth in the need for donor organs—are behind the ongoing debate about brain death and the growing movement to redefine what constitutes death, he notes.

The first attempt in U.S. history to redefine death was a 1968 article in the *Journal of the American Medical Association* that established criteria for irreversible coma. The article's primary purpose was to set forth a basis by which physicians could determine when a comatose patient could be declared dead.

The criteria listed by the authors were unreceptivity and unresponsivity (total unawareness of externally applied stimuli and inner need), lack of movement, breathing and reflexes, and a flat electroencephalograph (EEG) for 24 hours.

"Today we continue to define death according to brain criteria," Shannon says. "That's okay, because given the technology we have to maintain heart and lung function, death can be masked. What's critical is that death must now be 'whole brain,' including the brain stem," which regulates basic biological functions.

The authors of the 1968 study gave two important reasons for their new definition, Shannon points out. "One was to empty hospital beds in intensive care units; the other was to get fresh organs." He says such utilitarian thinking is at the heart of most of his concerns about medical and biological ethics.

The need for donor organs for transplants is undeniable. "More people need organs than get them," he says, noting that the reasons for the organ shortage include religious beliefs, the reluctance of many people to allow their bodies to be used for spare parts like so many junkyard cars, the lack of information about how to become an organ donor, and fear—perhaps not always openly expressed—that the medical establishment cannot be trusted.

The organ deficit has led to pressure to find ways to increase the supply, and that pressure has led to further efforts to redefine death, on the one hand, and new strategies to obtain organs—human or animal—on the other. Among those strategies are broader education efforts, as well as required request and opt-out programs.

Most states have laws establishing required request programs, which mandate that physicians and hospitals ask dying patients and their families for permission to remove useful organs immediately after death. While they can put pressure on families, Shannon says such laws protect an individual's right to decide what happens to his body.

Currently, there are no U.S. states with opt-out laws, though some European countries have adopted them. The underlying assumption of such laws, which allow physicians to take a patient's organs after death unless he has requested in advance that they not be removed, is that, "when you die, you become the property of the state." If you can become the property of the state when you die, Shannon reasons, what will prevent the state from starting to see you as its property before you die?

"One might think of fetal tissue transplantation," he says. "It's one thing for a woman to donate tissue from an abortion. It's another to simply take those tissues. That's an example where needs could drive practice. It's unlikely that the practice would be extended to the taking of blood, bone marrow or organs from living people, but the wedge would be there. It's a wedge issue."

Shannon is equally critical of thinking that leads to the conclusion that, because the technology exists to transplant organs, because there are people whose lives could be extended through this technology (or who can afford to pay for the technology), and because there are insufficient organs to supply all those who could benefit, we should increase the supply by loosening the accepted definition of what constitutes death. He says he is especially concerned that the definition is becoming centered more on the cognitive function of the brain, rather than on the whole person.

Shannon says he does not believe technology and science are value-free, but rather are driven by underlying social values. And the value that underlies the attempt to redefine brain death overemphasizes the ability to think abstractly. He says he questions why intelligence and the capacity for abstract reasoning should be valued more highly than other human qualities.

A person may value the ability to reason abstractly, but that capacity isn't explicitly what gives a person value. At least I wouldn't think so. You can't define a person exclusively in terms of any one particular value. It's not any one thing—or even the sum of all our particular capacities—that make us valuable. I think it's something that goes a little beyond that.

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In his 1985 book, *What Are They Saying About Genetic Engineering?*, Shannon argued that the tendency in our society to equate mental ability with human value sometimes leads us to socially disvalue people—such as individuals with Down's syndrome, sufferers of Alzheimer's disease, elderly patients in nursing homes or students in special education classes—who have a diminished capacity for abstract reasoning.

This tendency to equate human beings with fully functioning brains was reflected dramatically in a recent court battle in Florida over a baby born with anencephaly, a nearly always fatal condition in which most of the brain is missing. The parents of Theresa Ann Campo Pearson were willing to have her declared brain dead to assure that her organs could be removed for transplantation while they were still usable. However, the fact that her brain stem was functioning precluded doctors from making this declaration.

The arguments made in the case included the idea of excluding "infants without intact brains from the current definition and to consider them dead by virtue of brain absence," Shannon notes. It was, in effect, an attempt to redefine brain death solely in terms of higher brain functions.

"Such a shift in definition assumes a normative link between biology and personhood and comes close to deriving personal status—if not personhood itself—exclusively from neural activity," Shannon wrote in a recent paper on the case. In that paper he concluded that singling out one aspect of a human being and valuing it above all other aspects demeans human dignity.

"In one sense, human value is an abstract concept," he says. "On the other hand, we certainly have to concretize it in some form, but once you begin to concretize it outside of a certain context, you blow it. As soon as you isolate it for study, you kill it." This phenomenon is not unlike Heisenberg's uncertainty

principal, which says that the more accurately one measures the velocity of a moving particle, the more uncertain its location becomes, and vice versa.

"A lot of times, when you study something by isolating it from the whole system, you lose a big part of it," Shannon says. "For example, the first patient a doctor treats is a cadaver. On the one hand, you can learn a lot from that. But on the other hand, there is a lot missing."

Shannon says a host of similarly unarticulated and unexamined social and ethical issues surround biotechnology, especially in such areas as genetic engineering and genetic screening. For example, he says he is concerned about the fact that as a society we often fail to distinguish between a carrier of a genetic disease and someone who has the disease.

"A carrier is not afflicted by the disease," he says. "Genetic screening programs can identify both types of individuals, but if the distinction between them is misunderstood or confused, carriers could be prevented from receiving insurance policies or other health care benefits because of a wrong assumption that they are unhealthy.

"Not only might such individuals be unjustly deprived of a variety of benefits, they are unfairly labeled, and this can serve as a basis of discrimination." Already, he notes, a number of corporations and government departments have attempted to use genetic tests to screen out employees with genetic traits that might make them more susceptible to the harmful effects of chemicals or other occupational hazards.

However the ethical issues of genetic engineering develop, Shannon, who is about to begin work on a new book on the topic, will be there. He is also part of a research group at the Center for Theology and the Natural Sciences (CTNS) that is studying the theological and ethical issues raised by the human genome project with a $400,000 grant from the National Institutes of Health (NIH). The Human Genome Initiative, as it is officially known, is a massive national project aimed at mapping the location of every human gene, a development that will have unimaginable implications for genetic technology.

CTNS launched its study in the fall of 1991 to bring together geneticists, theologians and ethicists "to discuss the implication of human genome research for understanding the relationship between God's creativity and human creativity, biological determinism and free will, our ethical responsibility for the future, and the role Judeo-Christian religions play in cultivating social attitudes and offering genetic counseling."

The grant for the CTNS study came from funds specifically reserved by NIH for looking at the social issues surrounding the human genome project. "Three percent of the budget is earmarked for analysis of its social and ethical implications," Shannon says.

These issues might include who will control the intimate details about individuals that will be revealed as the genome is deciphered. "People are talking about having genetic screening done at birth," he says, "so we have a privacy issue here: Who controls your genetic profile, you or the state?

"The issue of control is significant and a major question we have to deal with. We don't want to make genetic information the exclusive basis for how we treat people. Genes are not the sole determining cause of who we are."

Shannon says the expectations many scientists appear to hold for the genome project worry him. He says many researchers have expressed the hope that "we're going to be able to cure diseases and make people the way we would like them to be—to be in charge of evolution. I don't think that's going to work."

Part of the problem I see in the genome project is that not all the communicators sufficiently attend to the context in which the gene operates—namely an organism or an environment. The fallacy that underlies genetic therapy, for example, is the assumption that if you have good genes you are going to be healthier. But there are environmentally caused diseases. You can have a decent set of genes and still get sick.

To begin with, he says, there are often complex relationships between genes that are not illuminated by simply knowing their locations. For example, the gene that makes one a carrier of sickle cell anemia also imparts an enhanced immunity to malaria. But beyond those concerns, geneticists must keep in mind that not all diseases have genetic causes and not all human qualities have genetic origins.

"Part of the problem I see in the genome project," he adds, "is that not all the communicators sufficiently attend to the context in which the gene operates—namely an organism or an environment." In particular, he says, environmental effects on health are sometimes overlooked. "The fallacy that underlies genetic therapy, for example, is the assumption that if you have good genes you are going to be healthier. But there are environmentally caused diseases. You can have a decent set of genes and still get sick. The bottom line is: be careful of exaggerated claims."

Shannon says he is also wary of the consequences of knowing too much about one's genetic makeup. "It's clear that some of what we learn might be bad," he notes. "It may also be problematic." For example, he asks, will learning that your genetic constitution might make you susceptible to heart disease at a young age spur you on, or leave you overwhelmed by the prospect of a potentially shortened or constrained life?

One question the NIH is not asking, Shannon says, is whether the human genome project should be carried out at all. Despite that omission, he says this "set-aside" will make possible the ongoing evaluation of ethical issues as the project moves forward, enabling the discussion to keep up with technological developments, instead of following them, as most often happens.

The need for that kind of thinking and discussion is urgent, Shannon says, because we have already seen how technologies can have unexpected implications and unanticipated applications. "Until we had good technologies for screening genetic diseases—and now genetic tendencies and traits—we couldn't attempt it," he says by way of example. "Now, because we can do it and because it's cost effective, there's more of an incentive for insurance companies to use the technology [to evaluate people]. So now we have a new problem."

For Shannon, this is another example of how technology can come to drive human action, rather than carefully thought out human values determining when and how a particular technology will be used. He traces this anomaly to the values of the free market system and to our notion that progress is linear. Not all cultures share this notion, he says; some don't even have a model of progress.

Indian culture, for example, has historically been governed by a cyclical model of time. "Obviously, you progress in time, but it's not directional," he says. "We in the West have the sense that we're going somewhere, even though we may not know where that somewhere is. The direction is typically upward and clearly forward."

The hospital "crash cart" is an example of how progress can be seen as inevitable. Every hospital floor has a crash cart for emergency resuscitation, Shannon says. "Well, there it is. Now what happens if you don't use it? Well, you get chewed out for having equipment that you don't use. And because you're not using it this year, you can't buy any new technology next year. So you use it. And you don't always ask, 'Should we use it?' Its very presence there—and the economic context—really mandate its use."

Shannon has applied his willingness to ask questions and peel back each layer of an issue to a number of other polarizing topics, including abortion. In doing so he has often taken a careful look at the science behind the issues. For example, in a paper titled "Reflections on the Moral Status of the Pre-embryo" published in *Theological Studies*, Shannon and Allan B. Wolter, O.F.M., examine in meticulous detail the development of the fertilized egg in an attempt to establish when one can begin to refer to it as an individual human being. Their goal was to encourage theologians to take biology into account in discussions about abortion.

"The best of medieval theologians argued within the context of their knowledge of biology," Shannon says. "We're simply doing the same thing with our model. It seems to me that the only reasonable way to discuss any kind of biological entity is to discuss it within the frame of reference in which you understand it, which is biology. But it's a model capable of enormous revision, so you have to keep rethinking in light of new knowledge."

In his classes at WPI, Shannon tries to get his students to apply similar analyses to ethical issues. In particular, he teaches them that there are such things as better arguments and worse arguments and urges them to learn to distinguish one from the other, not only in his class, but in the work they will do as engineers, scientists and managers. This approach has helped make him one of the Institute's most popular instructors (he was rated the best college professor in the city in a *Worcester Magazine* readers' poll a few years back). Students say Shannon's classes challenge them to express their thoughts and feelings, and to marshall arguments to support their views.

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Shannon says his own views about ethical issues have been shaped, in part, by his moral and religious background. He entered a seminary as a young boy, an experience he says exposed him to the world of scholarship—a world for which he seemed well suited. He was later ordained a Catholic priest, though by the time he reached his early thirties he had come to realize that he was better suited temperamentally for a secular life. He requested and was granted a dispensation from his vows.

His leaving the priesthood was not, however, a departure from the Catholic Church. His years in the church helped shape his views on medical ethics and the morality of war, and also gave rise to an ongoing interest in methodology, especially in Roman Catholic moral theology. Shannon is respected in Catholic theological circles, even if his views are not always in sync with the highest levels of the church. For example, his article on the moral status of the pre-embryo prompted a six-page letter from the National Council of Catholic Bishops, which noted that the views he and Wolter expressed were "open to dispute."

Shannon's debates with Catholic dogma stem from his dedication to weighing, not just theological and moral issues, but the most up-to-date research in biology and medicine. His arguments have also benefited from his efforts to experience firsthand the reality of modern medical practice. Since 1987 he has been a member of the Ethics Committee of Memorial Hospital in Worcester (now the Medical Center of Central Massachusetts—Memorial), where he goes on obstetrics and gynecology rounds with physicians and nurses and also conducts regular ethics rounds, particularly in the neonatal unit.

"The purpose of ethics rounds is to alert physicians to the fact that the issues they face are not exclusively medical," he says, "that there are ethical issues, value issues, choice issues (the patient's), and cost issues that go along with a particular treatment."

For several years Shannon was also a part-time associate professor of medical ethics at the University of Massachusetts Medical Center in Worcester, the only teaching hospital in the state university system. While there he directed the ethics segment of a program that instructed young physicians in patient care.

With those young physicians, as well as with the students who take his courses at WPI, he has always endeavored to impart a sense that there are no questions that can't be asked, for it is only by avoiding the tough questions that our society will continue to blindly embrace new technology.

"Don't be afraid of progress," he says, "but don't let it become our master. We have to recognize that as human beings we have built-in limits. So we have to think about our sense of priorities, and be cautious in our expectations of what modern medicine can do for us."

JANET WOODCOCK

Meeting the Need to Lead: *Thoughts on the WPI Experience*

By Francis C. Lutz, Dean of Undergraduate Studies

Editor's note: Each fall WPI's New Student Orientation gives entering freshmen a chance to get used to their new school—and to learn about the ins and outs of student life at the Institute—before the rush of classes begins.

In between the talks on residence hall living, the grading system, computer resources and so on, these young scholars spend a few minutes with the dean of undergraduate studies, whose duty it is to share with them his own vision of what makes the Institute a special place, and to introduce them to the intellectual adventure on which they are about to embark.

The following is excerpted from the talk Frank Lutz gave last fall to the students of the Class of 1995 and their parents—his first such address as dean of undergraduate studies. As the WPI community prepares for the start of yet another academic year—with all of the achievements and challenges it will bring—we thought it might be worthwhile to take a look back at this timely message.

Good afternoon. As members of the Class of 1995, you are now part of a community of scholars in a place where liberal learning and creativity are held in honor. In fact, the faculty here value learning so much that two decades ago they created a curriculum that, with proper effort on your part, will prepare you uniquely well for the challenges that face this nation and the world as we approach the next millennium.

Today I'd like to tell you how I think a WPI education will help prepare you for the future. But before I do, let me tell you something about myself. I came to WPI in 1972 as an assistant professor of civil engineering. I'd intended to stay for just a year or two, but have instead been here for nearly two decades. I hope you find the same feeling of community that keeps me here. (Of course, I hope you earn your degrees in fewer than 20 years!)

In 1974 my wife and I moved to Washington, D.C., to open WPI's first off-campus project center. The year before, I and the students selected to undertake the first projects in Washington had traveled there to meet with representatives of the agencies that proposed those projects and to lay the groundwork for the center. While in Washington, we stayed at the Howard Johnson Hotel from which the Watergate break-in had been coordinated.

It was a memorable experience to be establishing a program in our nation's capital while impeachment proceedings were under way against the president of the United States. Since then, some 600 students have completed projects in Washington—something of which I am quite proud.

What else of consequence was happening around that time? Well for one, most of you were born. In addition, New York's World Trade Center was completed; Billy Joel released his *Piano Man* album; Thomas Pynchon published *Gravity's Rainbow*; the Apollo moon landing program ended; Skylab was launched; and the selective service ended, as did two decades of U.S. military involvement in Vietnam.

The parents here today have quite personal memories of those events; the students remember them as history—as you would any event that occurred before your birth. Years from now, you will have vivid memories of some of today's events, especially the turmoil taking place in Russia. The coup placed Glasnost and Perestroika in jeopardy, but freedom is too appealing to be denied. The free-market economy, even with its imperfections, is a better provider than communism.

The world is changing, and it will continue to change rapidly. Germany's reunification came upon us with surprising speed. The European Economic Community is poised to become a formidable global economic force. In 1997 Hong Kong will no longer be a British colony.

Each of these events—and the manner in which our lives are influenced by them—will be colored by the technological advances of your lifetimes. But the social and cultural forces at work are also critical to an understanding of how these influences will be felt by the people of the world.

The sense of ethics that led to the resignation of Richard Nixon, the craving for freedom moving Eastern Europe toward democracy, the fear of the unknown and the repudiation of the past that Russians feel today, the genuine desire for German to reunite with German, and the concern mothers and fathers in Hong Kong feel for the futures of their children—these are all elements of our world that deserve your

The late professor Thom Hammond, left, with two WPI students in the early days of the Washington, D.C., Project Center. Founded during the Watergate crisis, the center opened in 1974, shortly after the resignation of President Nixon.

study. At WPI you will have the opportunity to meet fellow students from these and other regions of the world—to learn from them and to benefit from the differences they share with you.

We are each of us different. And in an atmosphere of respect for intellectual discourse, we should celebrate those differences. We should be moving closer to achieving Martin Luther King's dream of a world where all people are judged not by the color of their skin, but by the content of their character.

There are many things to learn beyond the world of academics, and you will be encouraged to learn them while you are here—things like a code of ethics, a standard of conduct and a sense of honor. It's from these sources of learning that hope for the future draws its strength.

I'd like to share three quotations with you. The first is by Mark Twain, who once said—and I'm paraphrasing—that when he was a boy of 14, his father was so ignorant he could hardly stand to have him around. But when he got to be 21, he was astonished at how much the old man had learned in just seven years.

The second is by Plutarch, who wrote that the mind is not a vessel to be filled, but a flame to be kindled. The last is from a Commencement speech that Rossiter W. Raymond delivered at WPI in 1879. Speaking about WPI's educational program, Raymond said:

"First, it is an experiment; secondly, as far as the experiment has gone, it has resulted in a highly satisfactory degree of success. The problem of education is a progressive one. The conditions are perpetually changing, and to a certain extent, these changing conditions peremptorily dictate corresponding changes in means and methods."

These quotations convey much about WPI: about the

NEIL NORUM

Above, Professor Fred J. Looft III, left, and Dino Roberti '85 look over the first MITRE/WPI experiment package. For Randall Briggs '86, opposite, an IQP was the start of a research project that led to his pursuing a Ph.D. at WPI.

faculty's focus on education as a continual process of learning that there is always more to learn; about the emphasis we place on creativity and inspiration, which provide the motivation to learn; and about the innovative spirit of experimentation and striving to be more than we would otherwise be, which we seek to instill in our students.

As you think about the time between now and May 1995 (a time that will pass all too quickly), I hope you keep these thoughts in mind. As you prepare yourself to play leadership roles in engineering, science, business, education, politics or government, these aspects of a WPI education will serve you well.

WPI's educational program is particularly well-suited to those students who feel what I have come to call the need to lead. Who are these people? They are

- Those who recognize the country's need for leaders who can recapture our international competitiveness
- Those who take no pride in the failure of our elementary and secondary educational systems
- Those who recognize that we will need new design approaches to keep our country's man-made infrastructure from collapsing
- Those who see the enormously important wave of economic and social change sweeping the world as a movement in which to participate, not just observe
- And those who see as a social need and a vast economic opportunity the construction of an infrastructure to help meet the needs of Eastern Europe, Russia, Southeast Asia, Latin and South America, Africa and the lesser-developed countries

Before I talk about the special attributes of WPI's academic programs, it might be valuable to go over some of the unique aspects of the WPI Plan. Our academic year consists of four seven-week terms. Students take three courses each term (each is worth 1/3 unit—16 units equals four years of study; 15 units are needed to graduate). The only grades awarded are A, B and C (grade reports that are blank because a student earned less than a C in every course are called snowflakes in WPI slang).

To graduate, a student must complete four physical education courses, broad distribution requirements in areas of study pertinent to his or her major, two social science courses, a Major Qualifying Project or MQP (which deals with a problem in one's major field of study), an Interactive Qualifying Project or IQP (which relates science and technology to social concerns and human needs), and a Sufficiency or minor in the humanities.

Now, how does this hodgepodge prepare you for leadership? Well, the faculty might say that you will never be marked with a failing grade for trying to master the content and concepts of any course at WPI, for if you are indeed lamps to be lit, and not buckets to be filled, we shouldn't dampen your spirits by labeling you a failure.

Equally important, with seven-week terms you will not be burdened to the point of distraction by juggling six courses at the same time, struggling to master more facts than you can possibly assimilate. At WPI you will be responsible for three courses or their project equivalents at any one time. Of course, you will be responsible for learning the content of those courses fully, a responsibility that should require more of you than you might think.

Then there are the projects—the MQP, IQP and Humanities Sufficiency. The practice of engineering, the conduct of scientific inquiry, and the management of organizations do not depend on turning in homework, but on completing projects on time. To tackle projects one needs a mastery of technical disciplines (you will develop that by turning in your homework), a command of scheduling, the ability to work as part of a team, and communication skills. Above all, one needs the ability to synthesize information and solve problems.

Certain of the projects prepare you for challenges that lie beyond the narrow confines of your technical discipline. Few engineers and scientists remain strictly within their original disciplines for more than a decade or so. Successful practitioners often move into management, where they must work with and compete against graduates of liberal arts programs. In addition, engineers and scientists must offer leadership—not just in technology development, but in the public use of that technology.

No matter what your major, the MQP should provide a culminating experience in that discipline, help you develop self-confidence, enhance your communication skills, and ensure that you can synthesize the fundamental concepts of the field. If your major is chemistry, you will achieve these goals in the laboratory, using state-of-the-art technology to examine advancing theory. If you major in management, your MQP will likely focus on the increasing role that technology plays in modern production. In mathematics, you might complete a theoretical thesis exploring graph theory or the motion of stellar systems.

With the diversity of intellectual opportunities available—a real strength of the MQP program—the learning experience can be tailored to the educational needs and individual interests of each student. Still, this diversity can get in the way of forming a true picture of the benefits of the MQP. Because so many of you are engineering majors, and because design is so integral

to the engineer's experience, let me use a group of engineering-design projects as an example of the substantive experience of the MQP.

The MITRE/WPI space shuttle projects program produced an experimental payload that was launched on the space shuttle *Columbia* on June 5, 1991. We are now decoding and analyzing the experimental data that the package gathered. The experiments were developed by undergraduate students working with WPI faculty in MQP teams and were financially and technically supported by NASA, MITRE Corp., AT&T, Raytheon, Digital Equipment Corp., Norton, General Electric and many other sponsors. (MITRE's support has been continuous since the start of the program in 1982; the corporation is now helping WPI students develop a second set of experiments we hope to launch during your academic careers here.)

Among the experiments was one that sought to grow large and potentially valuable zeolite crystals in microgravity. Another studied the behavior of fluids in space. Student teams also developed an electronic system to record data on the environment inside the canister that housed the experiments; the power supply and distribution systems; the control and monitoring systems; and a physical structure to support and protect all of this. Typical of WPI, the payload also carried an experiment on film fogging designed by a sixth-grader.

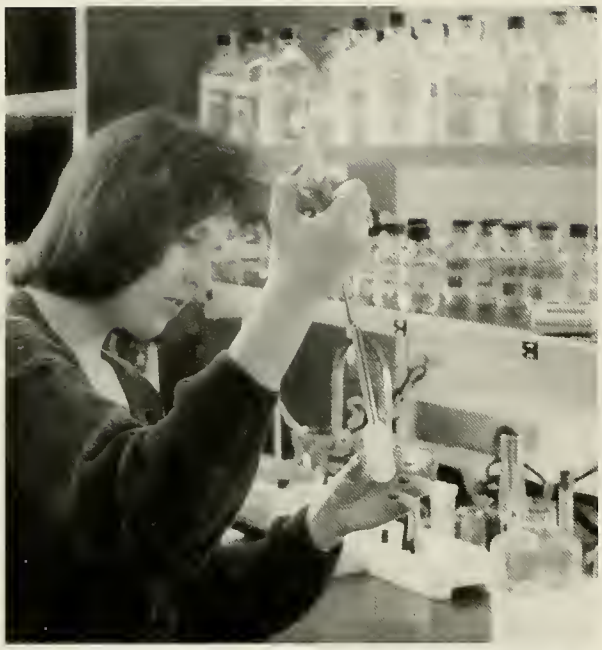
Just as engineers in the real world must face trade-offs, the students had to determine how much of the package's limited space and weight to allocate to each experiment and how much battery power each would be allowed. This was a valuable experience. As a result, I can assure you that while there is a lot of good solid science and engineering in the experiments, there is also a lot of camaraderie, long nights of trial and error, friendships and linked careers.

Some of you may find the idea that your graduation will depend on the completion of a project like this a little intimidating. I can assure you that the shuttle program students had the same feeling when they were starting their college careers. They stretched themselves, and their project advisors were there to help. Think of the special feeling those students (now alumni) must have today. Then think about how the faculty must feel about the accomplishments of those students.

Just as it will not be possible for a truly educated person of the next century to be ignorant of technology, nor can a technically based education be thought of as well-rounded unless it has a strong liberal arts component. Recognizing the growing importance of the interaction between technology and society, the WPI faculty developed the idea of the IQP in the early 1970s.

Today WPI is providing opportunities for students to complete their IQPs at project centers around the world. In addition to the center I helped establish in Washington, D.C., we now have residential programs in London, San Francisco, and San Juan,

JANET WOODCOCK



MICHAEL OORSEY

Christina G. Correia '92 worked on basic research in genetics for her MQP, one of a wide range of ways undergraduates can complete this versatile project.

Puerto Rico. We have project programs in Bangkok, Hong Kong, Taipei and Venice. WPI has also established foreign exchange program agreements with technical universities in Belgium, Canada, Ecuador, France, Germany, Ireland, Italy, Russia, Sweden and Switzerland. The learning opportunities in these countries create an atmosphere in which students can fully appreciate the global scope of the interactions between social and technical forces.

As you might imagine, topics for IQPs cover a broad spectrum. For example, one IQP group, working with the National Association of Manufacturers at the Washington, D.C., Project Center, reviewed federal policy on Superfund cleanups and its likely impact on corporate decision making. Several years ago a student analyzed the potential environmental impacts of mining on the moon. He recently received his Ph.D. in chemical engineering at WPI, completing his doctoral thesis on the feasibility of mining ilmenite on the moon to extract oxygen for a lunar base. I think Robert Goddard, a member of WPI's Class of 1908, would be proud.

Interactive Qualifying Projects like these have reinforced in the minds of the faculty the notion that integration is a powerful educational concept. At WPI that notion is particularly true in the humanities. A few decades ago, dissatisfied with the superficial approach to the humanities traditionally taken here and at other colleges and universities of science and engineering, the Institute created the Humanities Sufficiency. It has become the core of the college's commitment to the humanities as an integral part of the education of scientists and engineers.

Perhaps the best way to illustrate the nature of the Sufficiency is to provide two examples. To complete this degree requirement, students must take a thematically related sequence of five humanities courses and complete a culminating research project.

Here are the courses one student took:

- History of Technology
- European Technological Development
- American Science and Technology to 1859
- American Science and Technology from 1859
- Science, Technology and Society

His Sufficiency was called *Yorktown and Gettysburg: A Comparative Study of Strategy, Tactics and Technology.*

Another student took these courses:

- History of Technology
- Concepts in Philosophy and Religion
- Religion and Social Ethics
- Religions of the World
- Religions of the East

The Sufficiency was titled *The Engineer as a Whistle Blower.*

You may not have given much thought to how the humanities can make you a better electrical engineer; please give it considerable thought.

I've said the WPI Plan will prepare you for the future. But what will that future hold for you? Well, the engineer of the third millennium will probably have to make more out of less, designing to conserve already severely depleted resources. She will work with machines so complex that design adjustments will be made to "words" in computer programs, rather than to actual bolts or nuts.

Her education must give her a breadth of vision sufficient to see real social needs, as well as a depth of technical competence that will enable her to design more than just "gadgets of gratification." In short, it must be an education that is professional in content and liberal in scope.

What else will your future hold, and how will your world differ from mine and that of your parents? My generation saw the construction of the Berlin Wall; it also saw John Kennedy predict its demise with the simple but powerful declaration, "Ich bin ein Berliner." Most of you were alive for neither event, but in typically unpredictable fashion, you saw the wall come tumbling down.

No matter how encouraging, the changes we are observing in Russia and Eastern Europe are a beginning, not an end. What we are seeing is the consequence of man's

JANET WOODCOCK

Many students, including Beth A. Buscher '89 and Michael J. Carroll '89, standing, complete their IQPs by helping improve science education in the public schools.

From left, Daniel J. Smith '91, Tony M. Yee '91 and James C. Wilkinson '91 completed an IQP at WPI's London Project Center, one of several international project programs.

desire for freedom. These events hint at a more hopeful time than we've known before, but putting in place the economic infrastructures of a free enterprise system in those regions will be an arduous task, requiring truly educated leadership. I challenge you to make your contributions, and to take your places among those leaders.

When the European Economic Community unites at the end of 1992, it will mount an extraordinary challenge to America's economic future; that challenge will also be an extraordinary opportunity for the beginning of the third millennium. It is an opportunity for which you will be well-prepared.

You will also be well-prepared to appreciate the plight of the children of Hong Kong in 1997, and perhaps to lend them a hand. Last year a group of WPI students completed an IQP there in cooperation with the Office of the Registrar General. They sat over strong tea and discussed the implications of changes to Hong Kong's Basic Law. Other WPI students with equally important projects to undertake will assume their places in Hong Kong, in Washington D.C., in San Francisco, in Venice, in London, in Bangkok, in Taipei, and in San Juan. Where will your place be?

Alvin Toeffler's *Future Shock* of two decades ago brings to mind our inability to respond to rapid change. We at WPI must, as a recognized world leader of innovation in undergraduate education, be comfortable with change and encourage change relevant to the professions to which our students aspire.

For example, we have a special obligation to help improve precollege education in America. The parents here today should realize that their sons' and daughters' generation includes shocking numbers of individuals who will never acquire even the basic skills of literacy. They will be the core of America's work force, the men and women with whom your children—our students—will work to produce the world's goods and services.

We must take our obligation to improve precollege learning quite seriously. In that vein, I ask every student here today to consider volunteer service during your college career. Think of how you might contribute to the learning process for someone less fortunate than yourself—a youngster struggling with concepts you've already mastered. Develop a pattern of giving of yourself.

Feeling comfortable with change requires dialogue, thoughtful reflection and rational debate—that's what we do well here at WPI. Our curriculum is designed to develop these critical thinking skills, to make you aware of your responsibilities to society, and to help you apply your technical abilities and knowledge to the solutions of significant problems.

Without doubt, given enough resources, time and effort, today's technology can solve many problems, and can advance our collective understanding and social accomplishment significantly. Already during my lifetime, I've seen the development of a polio vaccine, the untold promises of recombinant DNA technology, the Apollo program's giant leap, satellite communications, and the exploration of the solar system. But technology can bring unanticipated problems as well as benefits. The challenge to today's generation is to answer the question of which technology should be brought to bear on which of society's problems.

WPI is much more than an academic community of high intellectual standards. It is also an environment carefully crafted to allow each student to meet those standards in his or her own way. College is many things to many people: it's the making of lifelong friendships; it's the process of learning to learn; it's a passage to scholarship; it's a community of traditions and common values; and it's a spirit of respect for intellectual inquiry.

At WPI, the college experience includes feeling Alumni Gymnasium shake from the roar of the crowd at a home wrestling match; walking through Alden Memorial on a rainy day and sharing thoughts with the portraits of the Institute's founders; and walking in the footsteps of former students like Robert Goddard.

It's remarkable that WPI's faculty has remained true to the commitment to educational innovation that Rossiter Raymond admired in his Commencement address more than a century ago. The consequence of that commitment is that the WPI curriculum is an innovative, substantive response to the need to lead.

It's a preparation for those who have the potential to recognize their deeper responsibilities to society, and to accept a leadership role, helping to set the direction of technological advancement for the country. It's a preparation that results in scientific and quantitative competence, a humanist's understanding of the applications of science and technology, and an appreciation for the social and cultural influences of the world in which we live. In Mark Twain's view, it leads one to appreciate all we have yet to learn.

I hope your time at WPI will prepare you well to seek that undiscovered knowledge. I hope you will find as you receive your degrees four years from now that we have met our obligation to you and to Plutarch, to fire your imaginations, to kindle your creative spirit and to ignite your hunger to learn. And once lit, I hope your flames burn brightly and truly illuminate the world.

Karen Berka: The Nancy Drew of the Crime Lab

As a young girl, Karen M. Berka '86 was addicted to Nancy Drew mystery novels. Today, like the young heroine of those stories, Berka also helps track down criminals and solve mysteries. But as a forensic chemist at the Indiana State Police Laboratory in Indianapolis, she uses tools and techniques that Nancy Drew might have found quite remarkable.

"I detect crime not with a badge and a gun, but by applying natural science to matters of law," Berka says. The daughter of Ladislav H. Berka, professor of chemistry at WPI, and Barbara Berka, a science teacher at the Bancroft School in Worcester, she majored in chemistry at the Institute and received her bachelor's degree with distinction. Inspired by a television interview she had seen as a seventh-grader with a woman chemist in the Boston Crime Lab, she went on to earn a master's degree in forensic science with a concentration in criminalistics at the University of New Haven in Connecticut.

Criminalistics is the branch of forensic science concerned with the examination of evidence, such as blood, body fluids, hair, fibers, drugs and arson accelerants. While at the University of New Haven, Berka did a summer internship in the criminalistics, fingerprint and firearms sections of the Maine State Police Crime Laboratory. She says observing actual casework and helping chemists and state police officers proved to be a valuable experience. "It was interesting to see how evidence was received and examined in the real world."

As a graduate student, Berka worked as a teaching assistant in the chemistry department and as a research assistant in the University of New Haven's forensic science department. In 1988, through a grant from the National Institute of Justice, she began working for the forensic science department full time as a principal research associate.

Before joining the Indiana State Police Laboratory, Berka conducted research at the Connecticut State Police Crime Laboratory, where she helped develop reliable methods for identifying human skeletal remains. "The work was based on the fact that human bone contains red and white blood cells," she says, "These cells contain genetic material, such as blood-group substances and DNA. We used the genetic information we obtained from the bones to individualize them."

"I detect crime not with a badge and a gun, but by applying natural science to matters of law."

This technique should prove useful in identifying victims of airplane crashes or explosions, when forensic scientists may have only bone remains to work with. In cases where only bone fragments are found, it will be possible to determine if they come from more than one person. The method may also help in the identification of the remains of soldiers missing in action in Vietnam and other wars.

From 1988 to 1990, Berka and her colleagues worked to refine the method used to identify victims' ABO blood types from genetic material found in the bones. Starting in 1990, they concentrated their efforts on recovering sufficient amounts of DNA to further narrow the identification of bone samples.

Berka and her research group published their findings in several national and international forensic science journals and made presentations at FBI symposia and at professional meetings around the world. Last year she attended the International Association of Forensic Scientists' triennial meeting in Adelaide, Australia, where she presented the data in a poster session. Delegates to the meeting came from all over the world, including Australia, England, France, Germany, Japan and Russia.

"I made valuable contacts with many scientists and police investigators," Berka says. After the meeting she toured Australia and visited the forensic labs in Adelaide, Melbourne and Sydney. She says she found it fascinating to see how another country deals with the analysis of crime scene evidence. She says she hopes to visit European forensic labs when she travels to the next international meeting in Germany in 1993.

In addition to performing research, Berka has taught an introductory course on forensic science for undergraduates at the University of New Haven. She belongs to Phi Lambda Upsilon, the chemistry honor society, and the chemistry and law section of the American Chemical Society. She is a trainee-affiliate of the American Academy of Forensic Science.

Berka, who worked in blood and body-fluid analysis during a six-month training period at the Indianapolis crime laboratory, says she is enjoying her new job. "I'm looking forward to eventually giving testimony in the courtroom," she says.

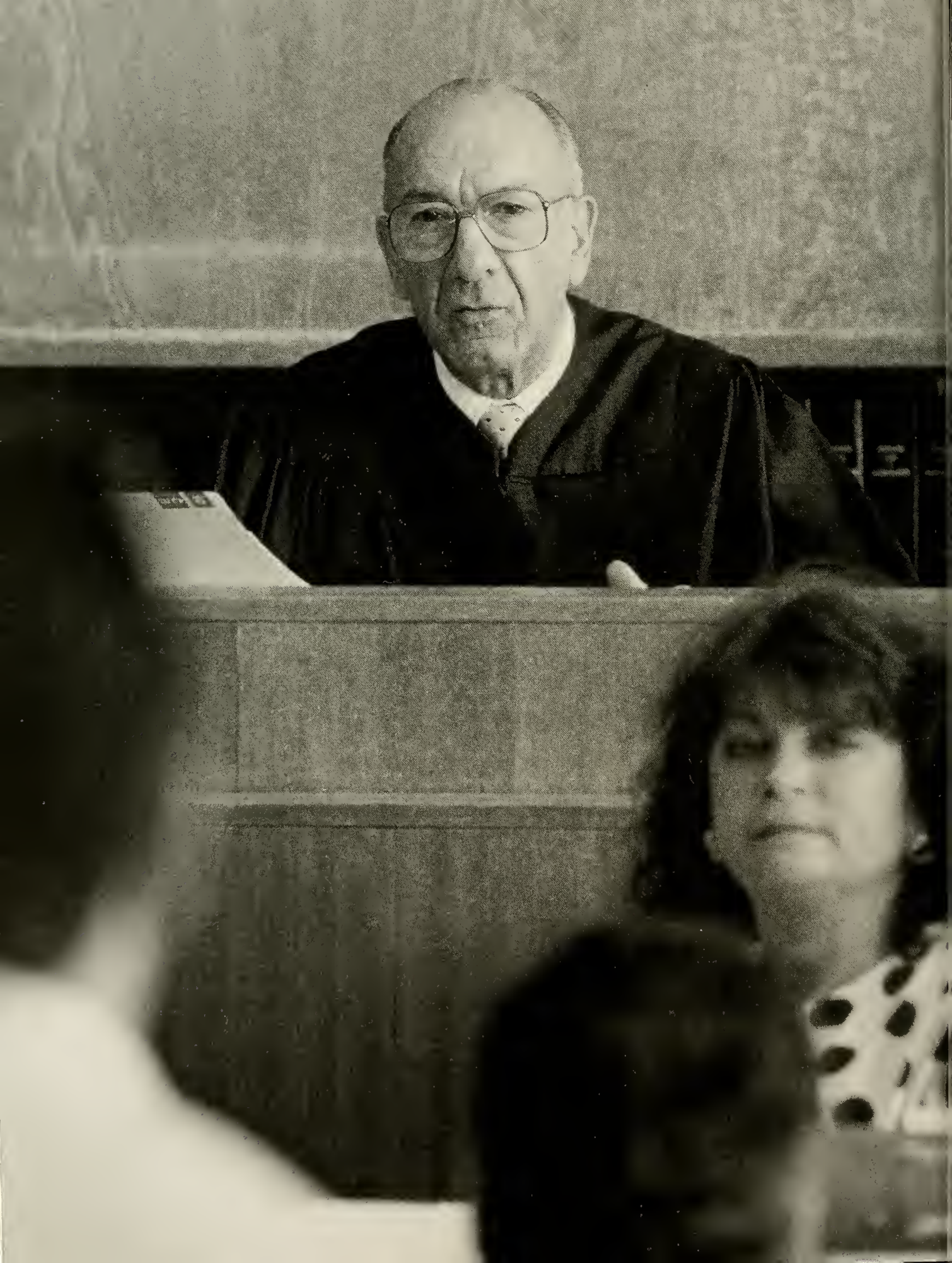
She adds that she still enjoys reading mystery novels and hopes to write her own mystery story based on her knowledge of and experience in forensic science. Several of her poems have already been published in local literary magazines.

—Ruth Trask

WPI Journal
WORCESTER POLYTECHNIC INSTITUTE
FALL 1992

The Unending Quest for Quality

Xerox Chairman and CEO Paul A. Allaire '60



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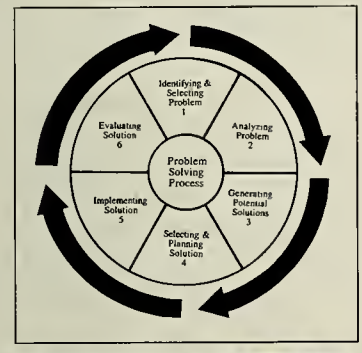

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Front Cover: Paul Allaire at Xerox headquarters in Stamford, Conn. Story on page 13. Photo by Ted Kawalerski. **Opposite:** Ernest Hayeck '47 in his Worcester courtroom. Story on page 36. Photo by Janet Woodcock. **Back Cover:** Astronauts Dick Richards and Bonnie Dunbar float before WPI's Zeolite Crystal Growth Experiment aboard the space shuttle *Columbia* in June. A photograph of Albert Sacco, head of WPI's Chemical Engineering Department, can be seen by Richard's left hand. Story on page 26. Photo courtesy of NASA.

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NASA PHOTO

Not So Wild a Dream

On a cold, sunny day early in 1991, a group of restless elementary school students files into the gymnasium of their school in central Massachusetts and the students sit in rows on the floor. They quickly settle down when the principal stands to introduce a tall, muscular man dressed in the familiar blue jumpsuit worn by U.S. astronauts. The speaker switches on a slide projector and instantly transports his young audience to a dreamlike world where people float gracefully through the air and gaze down on the brilliant blue-green planet below them.

As an alternate payload specialist for the first United States Microgravity Laboratory (USML-1), one of the most ambitious missions ever flown aboard a NASA space shuttle, Albert Sacco Jr. has already visited nearly 3,000 children in schools like this around the country, explaining how astronauts live and work in space and trying to get the next generation excited about the prospect of someday traveling into the final frontier as scientists and engineers.

For Sacco, head of WPI's Chemical Engineering Department, talking to young students about space is truly a labor of love, for it was as a youngster growing up in Belmont, Mass., that he himself caught the space bug. He was in second grade when the Soviet Union launched *Sputnik*. Later, as a sixth-grader, he thrilled to the exploits of Gagarin, Shepard and Grissom. In those early days of manned spaceflight, he decided that he, too, would one day know the thrill of riding a pillar of flame into orbit.

Over the years, when he was not working at Mario's, the Boston restaurant and bar owned by his former-prizefighter father, or making touchdown passes as the quarterback on the Belmont High School football team, he watched the launches and splashdowns on TV and filled a scrapbook with news clippings about the men who rode the rockets of Mercury, Gemini and Apollo.

He graduated from high school in 1968, just a year before Neil Armstrong took his giant leap for mankind. Though his father had hoped he might become a professional football player, Sacco's sights were still set on space.

Knowing NASA would need chemical engineers to design waste recycling systems for spacecraft, he enrolled as a chemical engineering major at Northeastern University. In 1973 he was accepted into MIT's Ph.D. program in chemical engineering. With a scholarship from NASA, he found a way to use the Bosch process, which converts carbon dioxide and hydrogen into water and carbon, in regenerative life-support systems.

In 1976, married and the father of two daughters, he applied to become an astronaut. One year before, three U.S. astronauts had docked their Apollo capsule to a Soviet Soyuz, bringing to an end the first great era of American space exploration. That era included *Skylab*, the first U.S. space station, which had proven that astronauts can perform worthwhile scientific research in the microgravity environment of low Earth orbit. Sacco knew that the space shuttle would build on that success, initiating a new era of space exploration that would demand a new breed of astronauts—space travelers drawn not from the ranks of military pilots, but from the cadre of university researchers.

After NASA turned him down, Sacco became convinced his chances of following his heroes into space had evaporated. But, as you'll read in the article beginning on page 26, 14 years later, having forged a successful career as an educator and researcher at WPI, he got a second chance.

While he is a step closer to realizing his dream, his role as an alternate payload specialist did not prove his ticket into space. Having completed NASA's rigorous astronaut training and flown a successful experiment aboard USML-1, Sacco says his chances of flying on a future mission should be good, providing he is willing to go through all over again the more than two years of intensive preparation required for the USML-1 mission.

NEIL NORUM

As a NASA payload specialist, Chemical Engineering Department Head Albert Sacco Jr. has talked to nearly 3,000 schoolchildren around the nation.

"I didn't have a vacation or a holiday during those two years," he says. "I didn't see my family but maybe 10 or 20 times during that whole period. That was a big sacrifice. Was it worth it? I think so."

Sacco won't say whether he will grab the chance to be part of another shuttle mission in a few years, should NASA extend the offer. It's just too soon to know how he will feel then, he explains. But in the end, his quest to be a space traveler may simply be too big a dream to set aside. As he told a writer for a Boston newspaper last year, "It's what could be that matters, not what is."

—Michael Dorsey

Here's Where the Money Goes at WPI

To the Editor:

Ever since reading the letter by Peter Schoonmaker '80 (Letters, Summer 1992), I have been troubled about how to respond. This is not because I disagree with Peter's facts, and certainly not because I disagree with the priorities he advances for WPI. It is the case, however, that we have been implementing the very priorities he outlines: "(1) student financial aid or tuition reduction, (2) faculty compensation, and (3) direct impact facilities such as classrooms, laboratories and student housing." That is, in fact, exactly where the money has been going!

Interestingly, the numbers Peter quotes from the 1990-91 annual report support this assertion. Table 2 from the Spring 1992 *WPI Journal* has been reprinted here, once again; I've augmented it with several additional numbers and have changed the FY 1991 figures to include institutional work study as financial aid, as it was in the FY 1985 numbers.

Table 2 (augmented) shows that total expenditures for financial aid were increased by 69.2 percent (9.2 percent average annual compounded) in constant dollars between FY 1985 and FY 1991. This is significantly more than other expenditure increases during that period. Moreover, the average annual percent changes in expenditures in constant dollars for the components of financial aid from institutional, endowment and external funds during that period were 22.7, 3.1 and -2.4, respectively.

TABLE 2 (AUGMENTED) SOME REPRESENTATIVE CHANGES IN ASSETS, REVENUE AND EXPENDITURES AT WPI

	FY 1985* (in millions of dollars)	FY1991* (in millions of dollars)	Change (in percent)	Compound Avg. Ann. Change (%)
Endowment	38.2	51.3	34.3	5.0
Tuition/Fees Revenue	12.4	18.3	47.6	6.7
Total Revenues	27.3	32.7	19.7	3.0
Instruction & Library	7.8	9.9	26.9	4.1
Financial Aid (including institutional work study)	3.9	6.6	69.2	9.2
Institutional Financial Aid	1.2	4.1	241.7	22.7
Operations and Plant Maintenance	2.2	2.2	0.0	0.0
Student Services	1.02	1.29	26.4	4.0
General Administration and Institutional	1.32	1.53	15.9	2.5
WPI Tuition and Fees (in thousands of 1978 $s)	4.8	6.6	37.5	5.5

*Constant Dollars, Basis: 1978 (Source: 1990-91 WPI Annual Report)

In other words, during that six-year period, when we increased total revenues (in constant dollars) at an average annual rate of 3.0 percent, tuition and fees revenue at an average annual rate of 6.7 percent, and tuition and fees themselves at an average annual rate of 5.5 percent, we increased financial aid expenditures from institutional funds at an average annual rate of 22.7 percent—nearly 3.5 times faster than tuition and fees revenue. During this period, undergraduate institutional financial aid grew from 10 percent to 23.5 percent of undergraduate tuition revenue. That sounds like a priority to me!

Also, as that period ended, we elected not to increase tuition rates for 1991-92 and have increased rates for 1992-93 by only 3 percent—essentially zero growth in constant dollars and about half the increases implemented by most of our peer institutions. That, too, sounds like a priority! Moreover, with our need-blind admissions policy, we work quite hard to make it possible, financially, for any qualified applicant to attend WPI.

Our priority on faculty compensation is more difficult to demonstrate from these data. Table 2 (augmented) shows that average annual expenditure increases (in constant dollars) were greater for in-

JANET WOODCOCK

WPI President Jon Strauss talks to alumni at Reunion in a renovated Alden Memorial.

struction and library (4.1 percent) than for student services (4.0 percent), general administrative and institutional (2.5 percent), or operations and plant maintenance (0 percent). Much of the real increase in instructional expenses was directed to a 10 percent increase in tenure-track positions over the period, undertaken both to accommodate a 7 percent increase in enrollment and to provide faculty more time for scholarly activities.

In recent years, we have kept our average salaries for assistant professors at the top of our comparison group in the Association of Independent Technological Universities in order to be able to attract and retain the very best young faculty. Unfortunately, the pressures of financial aid and our efforts to moderate our tuition increases have caused the average salaries of associate and full professors to slip to about the median of this comparison group. Providing competitive compensation to our productive faculty and staff is one of our highest priorities for the future.

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Fuller Laboratories is an example of a recent capital improvement that has had a direct impact on educational excellence.

The priorities expressed in our capital improvements in recent years (Founders Hall, Fuller Laboratories, Institute Hall, the new Biosensor, Bioprocessing and Ceramics laboratories, the communications network, and classroom, laboratory and residence hall improvements throughout the campus) conform well to Peter's stated priorities: "direct-impact facilities such as classrooms, laboratories and student housing." And, while Peter refers to the renovation of Alden Memorial (funded totally from external sources) as "a fringe benefit," the hundreds of students involved in our various performing arts programs and the many students, alumni and friends who benefit from the new meeting facilities in Alden would disagree vehemently.

Our latest physical improvement project, the new Fitness Center in Alumni Gymnasium (funded by gifts from the anniversary classes of 1952, 1953, 1967 and 1968) might also be questioned for how "it contributes to engineering and science education." But the more than 1,500 students and faculty who signed up to use it in its first week of operation would probably argue that this facility will help produce more of the "satisfied alumni" to which Peter alludes.

Moreover, this past year our students (customers, in our new jargon borrowed from industry) and faculty have recommended very strongly that a new campus center be given the highest priority in our capital project planning.

Peter faults our $450,000 landscaping budget without noting that it includes all costs for maintaining more than 60 acres of campus—including personnel, equipment, materials, snow removal, athletic field maintenance and, yes, even new flowers. That aside, it should also be noted that the total real expenditures for maintaining the physical plant did not grow during this six-year period, while new and renovated facilities added significantly to the underlying costs. Despite Peter's suggestion to the contrary, we find that our alumni, faculty, staff and students—and particularly prospective students and their parents—place a great deal of emphasis on the quality and attractiveness of our campus, both buildings and grounds.

Peter makes a clarion call for greater efficiency and more tough-mindedness on the part of WPI administrators and suggests, "WPI is not being managed responsibly." Without meaning to sound defensive, I suggest that WPI has been mindful of the changes in the society around it and quick to adopt those industrial practices that will improve its effectiveness as well as its efficiency.

While serving as an aide to former Education Secretary William J. Bennett, Chester E. Finn Jr., a professor at Vanderbilt University, received a lot of press attention for advocating the "no-frills university." We at WPI are quite mindful of the best implications of this concept, as evidenced by our success at continuing to improve quality while restraining prices.

We are not, however, about to sacrifice the very things that make WPI so special to us all in a mindless race to a generic engineering school model. And, our alumni, our students and our prospective students have made it clear that many things Chester Finn and Peter Schoonmaker would consider "frills" are important to their decisions to matriculate at—and their continuing enthusiasm for—WPI.

This past year has seen any number of significant accomplishments at WPI that have been chronicled in the pages of the *Journal* and the *WPI Wire*, including the retention of our No. 1 ranking among comprehensive universities in the North by *U.S. News and World Report*, the reaffirmation of our institutional accreditation by the New England Association of Schools and Colleges, the continued enhancement of our Global Perspectives Program, the establishment of the Center for High-Performance Computing, and the initiation of the Massachusetts Academy of Mathematics and Science at Worcester.

These notable accomplishments, to say nothing of the extraordinary quality of the education we offer our students, the scholarly contributions of our academic programs, and the many services performed in support of our society, were made possible, in large measure, by the dedication and hard work of almost every member of the WPI family and by the fiscal responsibility that is a watchword of this distinctive institution. And, most of these contributions would not continue without the strong advocacy and generous financial support of alumni and friends.

Having said all this, I certainly do agree with Peter's concluding notion that readers of the *Journal* should make themselves heard. If one measure of that is more giving designated for financial aid, there could not be a better outcome.

Jon C. Strauss
President of WPI

Perspectives on Technology and Society

To the Editor:

I was particularly interested in Diane Benison's piece on Thomas Shannon's work and thoughts on bioethics ("First, Do No Harm," Summer 1992). It is interesting that a research group such as the Center for Theology and Natural Sciences has been founded to attempt to bridge the gap between the underlying traditions of society and their perceived conflicts with science. However, it is somewhat frightening that many researchers (and society itself) seem to place such confidence in the ability of technology to lead us into the future through projects like the Human Genome Initiative. It reminds me of the old story about a man who could solve almost anything, if he could only figure out what the problem was.

In his 1985 book, *The Closing of the American Mind,* Allan Bloom asked many penetrating questions about the historical position of the natural sciences in Western traditions. He urged us to reexamine why "natural" science has become so estranged from philosophy and the humanities. This question is worth more than the lip service it is so often given, and I believe its examination is part of the key to resolving many of the agonizing issues we face, when, as Shannon suggests, "technology continues to outpace ethics and the law." One need only attend a public hearing on health risks from "hazardous" waste, and to observe the predictably emotional response often given to a dry presentation of toxicological data, to appreciate the inherent cross-cultural mismatch, suspicion and distrust that can so easily occur.

In the last 25 to 30 years we have witnessed the ostensible decline (for better or for worse) of many of the underpinnings of our traditional models of social guidance (i.e. religion and family). What is the relationship (if any) between these events and our increasing distance, as a society, from the complex world of specialized technology? The distrust in many traditional forms, including technology—especially by the young—and the simultaneous emergence of a myriad of "growth centers" seeking spiritual or psychological renewal (and not, incidentally, rejecting much that is material and technical), seem to be obvious manifestations of a society searching for a more balanced approach to living.

At the same time, few would disagree that the awe-inspiring discoveries of this period have evoked an almost religious sense that science is "truth," on the one hand, while on the other hand eliciting an intuitive feeling that this is not all of the truth—that somehow we must examine and appreciate things in a more humane context if true understanding and the best use of these discoveries is to be achieved.

In a second glance at several of the articles in the Summer *Journal*, I was struck by the use of spiritual metaphor. In "The Soul of a New Center," the Holy Grail is equated to new supercomputing systems; in "Genetics and the Great Shrimp Deficit," we learn we can now engineer domestic animals; and in "A Trillion Here, A Trillion There," there is an expressed sense of amazement at the incomprehensible, ending with a wonderful quote by the playwright Eugene Ionesco. Perhaps this comes a little closer to the practical man's acknowledgment that there is an increasingly important necessity to question the relationship between relatively abstract technological concepts and the everyday world in which we live. Perhaps we must even devote more than "three percent of the budget" to those profoundly human questions —including those that arise from our mystical and poetic sides—that are essential avenues for balancing our lives and culture.

Albert Einstein was able to see far beyond his own arena, as in these remarks quoted in *The New York Times* in 1952: "It is not enough to teach a man a speciality. Through it he may become a kind of useful machine, but not a harmoniously developed personality. It is essential that the student acquire an understanding of and a lively feeling for values. He must acquire a vivid sense of the beautiful and of the morally good. Otherwise he—with his specialized knowledge—more closely resembles a trained dog than a harmoniously developed person. He must learn to understand the motives of human beings, their illusions, and their sufferings in order to acquire a proper relationship to the individual man and to the community."

In the end, the quality of the work of our era is likely to be judged in relation to the service rendered to society by craftsmen from all trades striving toward more holistic goals. Enlightened self-interest requires another look at our approach to the question, "what should these goals be?"

Peter F. Kuniholm '61
Pound Ridge, New York

P.S. As a practicing consulting engineer who shares many of the concerns expressed in Peter Schoonmaker's letter (Letters, Summer 1992), I nevertheless find myself hoping that WPI, while maintaining the New England practicality that so many of us have benefited from, will all the same resist the call to become too narrowly focused on financial matters for their own sake. Surely we must be prudent, but I would urge emphasis on the seemingly abstract but critically important human questions of the sort being raised by Shannon. However, as with the concept of total quality management, the commitment to do so must come from the top if it is to be effective.

Big Numbers and "Wet Paint" Signs

To the Editor:

Re: "A Trillion Here, A Trillion There" (Advance Word, Summer 1992). I agree, the proliferation of large number usage by scientists, government agencies and politicians has numbed the mind of the general public to their real significance and meaning.

The largest numbers the average person will encounter in day-to-day activities relate to insurance, mortgage balance and miles shown on an automobile odometer. We can still relate to some degree when we hear of millions, but when we get to billions, trillions and light years our understanding goes off-track.

That is why it is comforting to see a "Wet Paint" sign. Now, here is something we can relate to; we can even test its validity with a single finger. Perhaps what the world needs are more "Wet Paint" signs to reassure us that there is still something in this high-tech world we can take comfort in being able to understand.

Richard C. Olson '50
Shrewsbury, Mass.

What Does Quality Mean at WPI?

It was a beautiful New England spring day. Corporate recruiters were on campus and the seniors were anxious, as their futures were beginning to take shape. Returning to Boynton Hall with just a few minutes to pick up some documents before heading out to yet another meeting, I bounded up the stairs to find that every available space in the second-floor reception area—from the chairs in the conference room to couches in the sitting area—was occupied by a student stooping over some papers.

I also noticed Joan Szkutak '79 of Procter & Gamble Co., whom I had visited just a few weeks before in Cincinnati. We greeted each other and I asked what was going on. She said the students were being tested—our students, who were being recruited by Procter & Gamble, were being evaluated by a company test!

I vividly remember that experience, because it made me think about an important question, one that I have been asking as a matter of course since then: who are WPI's customers? Certainly, our students are our primary customers, but they are by no means our only customers. As my experience that spring day reminded me, the industries that hire our graduates are also our customers. The parents of our students are customers, as are their friends. Our customer base also includes our alumni, our neighbors, the companies and agencies that support research at WPI, and the people who read about that research in academic journals. In a sense, the whole of society is a customer of WPI.

We also have internal customers. For example, faculty members who teach upperclass courses are, to a large extent, the customers of those faculty members who teach the freshman courses. Assessing the needs of all of our customers—external and internal—and ensuring that those needs are not only met, but exceeded—that is what quality should mean at WPI.

In my address before the 1990 Academic Convocation, I noted that Xerox Corp., under its CEO, Paul Allaire '60, had recently won industry's most coveted prize: the Malcolm Baldrige National Quality Award. I proposed that WPI strive to achieve a similar level of excellence. But the question left unanswered was how does one implement a quality program—one aimed at meeting customer needs—within higher education? One can start by looking at the criteria for the Baldrige Award. They are:

Leadership, the sustaining of a clear and visible value system that guides the activities of the institution,

Information and Analysis, a quality-related database supporting a system that insists upon management by fact,

Strategic Quality Planning, the integration of quality improvement efforts into the overall short- and long-term planning processes,

Human Resource Utilization, the providing of quality education and training, and the tying of performance measurements to quality objectives,

Quality Assurance of Services, the systematic and continuous improvement of critical processes within the organization,

Quality Results, the examination of quality indices (internal and external to the institution) based on analyses of customer requirements and expectations, and

Customer Satisfaction, being able to determine customer requirements and expectations, measure customer satisfaction, and improve the relationship/process once problems are identified.

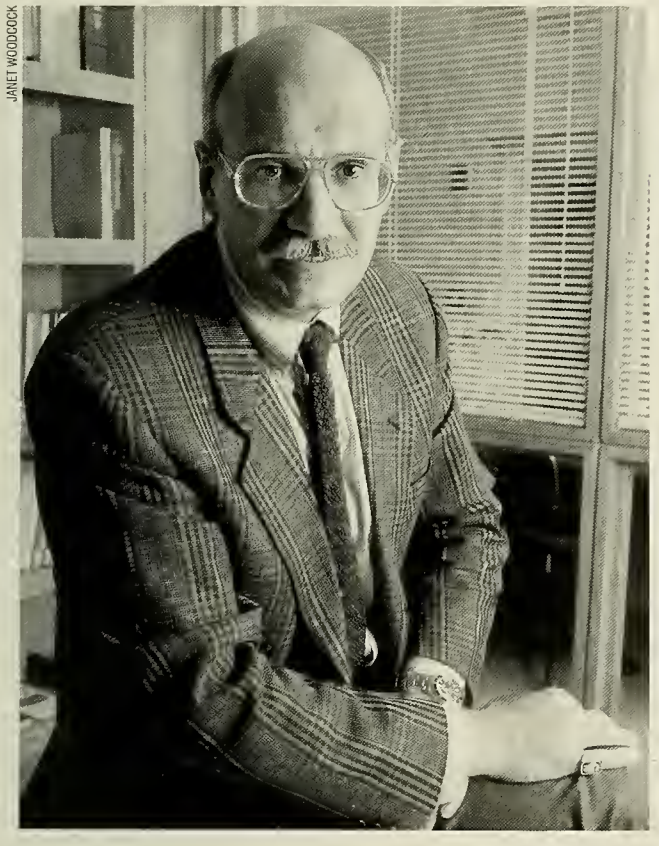
These are laudable and appropriate criteria, and we in higher education need to adapt them to the management of our institutions. But where do we begin? For the members of WPI's Blue Ribbon Task Force, a committee of faculty, staff, students and trustees that has been charged by the trustees and WPI President Jon C. Strauss to recommend measures to bring about financial stability at the Institute, based on a new vision for WPI and working within the framework of its strategic plan, that starting point was a training session at Xerox—at the invitation of Paul Allaire—on the principles and tenets of quality management.

The time we spent at Xerox was meaningful. But as we left corporate headquarters that day, we knew the challenge before us was to adapt the principles Xerox has used so successfully to our own business—higher education. As we thought about that challenge, a number of paradoxes kept creeping up. For example:

Student learning is difficult to measure. We do teaching evaluations in which students answer such questions as "Was the teacher well-prepared?" and "Does he or she present the material in an organized and clear manner?" But teaching evaluations are not exactly learning evaluations.

Student grades may be misleading indicators. The WPI Competency Exam seems like a better system than grades to assess learning. This terminal degree requirement, adopted and implemented by the WPI faculty as part of the WPI Plan, but later phased out in favor of distribution requirements, asked students to marshal all they had learned at the Institute to solve a real problem.

Academic freedom of the faculty and student satisfaction cannot and should not be in conflict. The faculty and the students should be partners in the learning process, each striving for the same goal: a challenging experience for students that stretches them intellectually and creates in them a passion for learning that will stay with them for life. In that endeavor, the faculty's need for freedom and the students' demand for



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WPI, like all institutions of higher education, can benefit from the quality principles being adopted successfully by major corporations like Xerox, notes WPI's provost, Diran Apelian.

a satisfying educational experience should be consonant.

These paradoxes are not impediments; rather they point out that we need a new model for higher education—a new paradigm based on quality principles. There are compelling reasons to consider adopting such an approach. Here are four:

- A significant portion of what many of us at WPI do could be classified as rework. We fix problems that keep repeating.
- Miscommunication seems to abound among the members of our community.
- Shared governance on campus seems to mean shared authority and not shared responsibility. Authority and responsibility ought to be inseparable.
- There is a great deal of "talking about each other," rather than "talking with each other."

WPI is a special place. The intellectual vibrancy and the commitment of the faculty and the staff to the Institute's mission is genuine. Institutional pride is abundant. Adopting quality principles will alleviate the process problems we've experienced and take us to a higher level of satisfaction about all we do.

So far I've addressed quality principles in a general way. Quite specific to our culture in higher education, I am proposing that we consider the following imperatives:

1. Synergisms and consonance of goals are required at all levels—from the president, to the provost, to the department heads, to the faculty, and to every member of the staff. Shared governance (shared responsibility, not just shared authority) between the faculty and the administration needs to be reinforced.

2. Decisions must be based on facts. This applies to policy *and* operational decisions and requires that every one of us be knowledgeable in assessing, evaluating, measuring and distilling the facts out of the data.

3. We must concentrate on fixing the process, not the problem. That means getting to the root cause of problems and fixing the underlying processes that give rise to them.

4. We need to benchmark at all levels. We must measure our strengths, our vulnerabilities and our opportunities against those of our competitors.

5. Training—at all levels—should be a high priority. In general, universities do not do a good job in this arena. We need to infuse much of our energies and resources into training and educating our staff. In addition, recognition, reward and performance evaluation should be aligned with the institution's quality objectives, which in turn should be based on its value system and its vision.

Benchmarking is an interesting case in point. It is crucial, for example, that the faculty be cognizant of the needs of industry. They should know what the industries that hire our graduates look for. They should also know the reasons why some industries don't hire our graduates.

But it is not enough to benchmark; we must work together to use the information we gather. It is important, for example, that our "production team" (the faculty) and our "marketing team" (our Career Development Office) work together to meet the needs of our industrial customers. Perhaps 5 percent of the faculty (on a rotational basis) should be involved with the Institute's placement function.

Similarly, the production team and the "sales team" (the Admissions Office) should be better aligned, perhaps by having 5 percent of the faculty be involved with the admissions function of the Institute. The way we run our "business" will dramatically change if we develop such cross-functional relationships.

The five imperatives I outlined above call for change. Such change will bring about total empowerment, a united community and an environment in which every person in the organization knows how crucial his or her job or function is to the institution's well-being.

It will bring an inner satisfaction to every member of the community to know that his or her contributions make a significant difference. But change is not easy; more accurately, it is very difficult. It requires shedding old views and rethinking anew. As John Kenneth Galbraith observed, "Faced with the choice between changing one's mind and proving that there is no need to do so, almost everybody gets busy on the proof."

At WPI we have committed ourselves to opening minds. We have worked to create an environment in our classrooms and laboratories that encourages students to question, to analyze and to synthesize. Now it is time for us to consider how quality initiatives can help us do these jobs even better. As I noted in my 1990 Convocation address, "Let us be recognized for our total quality program in everything we do. We will be the only college in the nation that will have implemented such a philosophy. Let us be the envy of our peers, and the college of choice for all potential students. I know we can do it; there are no limits to what we can do together."

—Diran Apelian

Apelian is WPI's provost and vice president for academic affairs.

Walking the Talk:
Management's New Philosophy of Quality

By Diane Benison

Before too long, there may be just two kinds of companies in the world: those that follow the philosophy of total quality management and those that go out of business. Here is the story behind this powerful technique and a look at how it's turned the tide for several major American corporations.

Editor's Note: *It's hard to pick up a professional publication in any discipline these days without reading something about total quality management (TQM), or continuous improvement, as it is also called. This approach to managing organizations first took hold in industry, but is now finding advocates in all sorts of institutions (see Communiqué, page 6, for a look at how TQM may find a home at WPI). In the pages that follow, the* Journal *explains how TQM works, how it can help make a corporation more competitive, and the steps an organization must take—and the commitment it must make—to adopt it. Then, starting on page 13, you'll find out how five major American corporations—and WPI's own Management Department—are putting the principles of TQM to good use.*

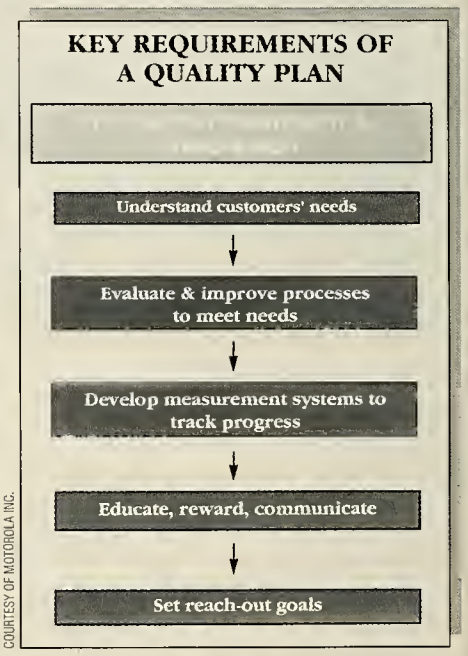
Total quality management isn't for everyone. Most certainly, it's not for the faint of heart, the impatient, the autocratic, or those who feel they've paid their dues and want to maintain the status quo until death or retirement, whichever comes first.

But establishing a corporate culture based on a philosophy of continuous improvement may be the single most important step a company can take to gain and maintain an edge in today's highly competitive marketplace. Some TQM proponents will go so far as to say that companies that don't institutionalize the philosophy of continuous improvement will simply not survive as global competition intensifies.

Xerox Corp., which was humbled in the 1980s as customers judged its products and services inadequate, credits its turnaround to a decision to adopt TQM (see page 13). Company representatives candidly explain that making the shift took more time and was far more difficult than expected. They also say the process of change was filled with setbacks.

But by sticking with TQM through these ups and downs, Xerox engineered a highly celebrated comeback. Its products are once again held in high esteem in the marketplace—something clearly reflected in its bottom line. And, as a result of adopting quality programs, the company won the Department of Commerce's prestigious Malcolm Baldrige National Quality Award in 1989 (see story, page 11).

Most consumers would agree that when they say a product has quality they mean it works well and doesn't break right away. But in the last decade the word has come to stand for much more than that. As defined by companies that espouse continuous improvement, quality products and services are those that satisfy customer expectations for function, performance and price. In the world of TQM, they note, it is the customer who defines quality, not the designer, the engineer, the assembler or the accounting office.



COURTESY OF MOTOROLA INC.

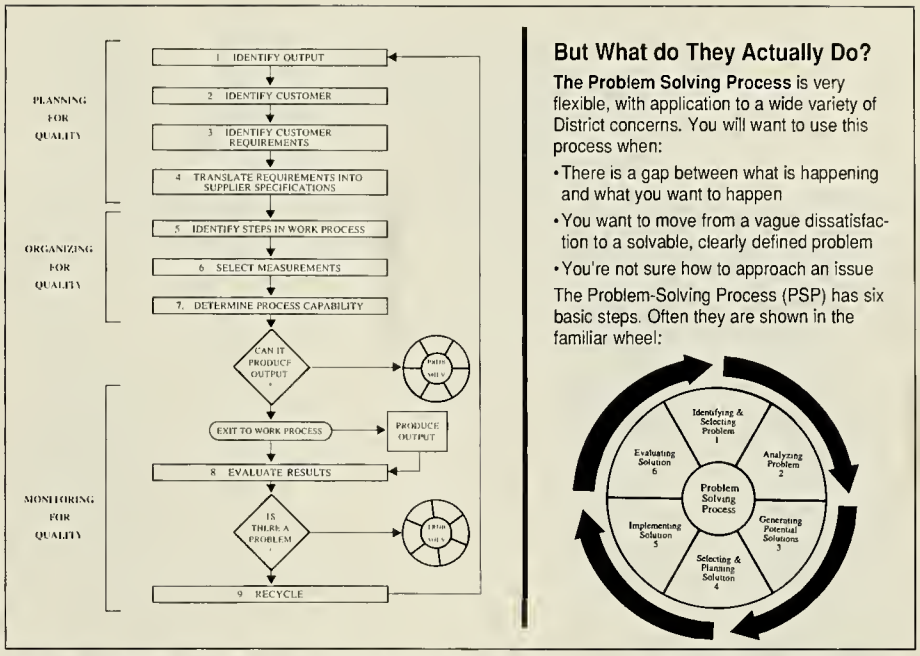
But the organizational model that still prevails in much of the U.S. workplace is an autocratic, hierarchical one where workers are told what to do by the layers of management above them. For this reason, implementing continuous improvement takes top-to-bottom change. First and foremost, it requires workers and managers to change their attitudes about each other, and to examine how they think about work.

Implementing a TQM program also means learning to use complex statistical and analytical tools. It means abandoning turf wars and politics-as-usual. It means replacing serial, segmented product devel-

opment and design with the principles of concurrent engineering. And it means learning to work cooperatively, listening to others, and empowering subordinates to act in the best interests of the customer.

Change of this magnitude is difficult, but the rewards are great, say those who've made the change, for a philosophy of continuous improvement can make a company more effective, efficient and profitable. Among other benefits reported by TQM companies: the time needed to move from conception to market with a new product is significantly shortened; scrap is reduced, saving money on raw materials and pollution control; fewer errors are made, saving employees time and customers aggravation; the cost of manufacturing is lowered; and customer satisfaction and loyalty are increased.

There is another benefit, one not often stated explicitly. While innovation can give a company a big boost in market share, and even create new markets (Xerox's 914 plain-paper copier and Polaroid's first instant camera are good examples), it is continuous improvement over time that truly gives a company an incremental advantage over its competitors. To survive and prosper, companies need innovation *and* continuous improvement.



COURTESY OF XEROX INC.

Like most companies that adopt total quality programs, Xerox has developed formal quality procedures and tools for its employees. Two key tools employed at Xerox are a nine-step quality improvement process, left, and a six-step approach to solving problems.

Whether it's called total quality management or continuous improvement, the goal of this new management approach is simple, to deliver a consistent product or service that does exactly what the customer wants. But how does a company go about turning that austere philosophy into a concrete approach to running a real organization?

What follows are 11 practical rules for doing just that. They are based on ideas culled from interviews with alumni at five major corporations and with researchers in WPI's Management Department.

1. Use Fewer Vendors and Make Them Part of the Quest for Quality

Companies that adhere to the principles of continuous improvement treat their vendors as partners. They tend to have fewer suppliers than most other companies and they hold them to the same standards of quality they apply to their own products.

They also bring suppliers into the design process as new products are being developed. This allows suppliers to enhance new products with their own technological expertise. Many TQM companies also have vendor certification programs that require suppliers and prospective suppliers to demonstrate that they can adhere to the firm's quality standards.

As it moved along the quality path, Xerox cut the number of vendors from which it purchases parts from more than 5,000 to about 450. At the same time, it increased the quality of the material and components it buys. TQM companies often open their training classes to their vendors, teaching them right along with their own employees to use the statistical and procedural tools needed to identify problems, reduce variation and produce consistent quality.

2. Let the Voice of the Customer Drive the Quality Process

Just as TQM companies must treat their vendors differently, they also change the way they interact with their customers. They listen to customers and gather data about them by observation. They find out how well their products are meeting the needs of their customers, and how those needs may change in the future.

When customer surveys uncover dissatisfaction, TQM companies find out what went wrong and work to fix it right away. More important, they delegate to the lowest possible level of the corporation the authority to make those fixes, and give workers the information they need to make the best possible business judgments.

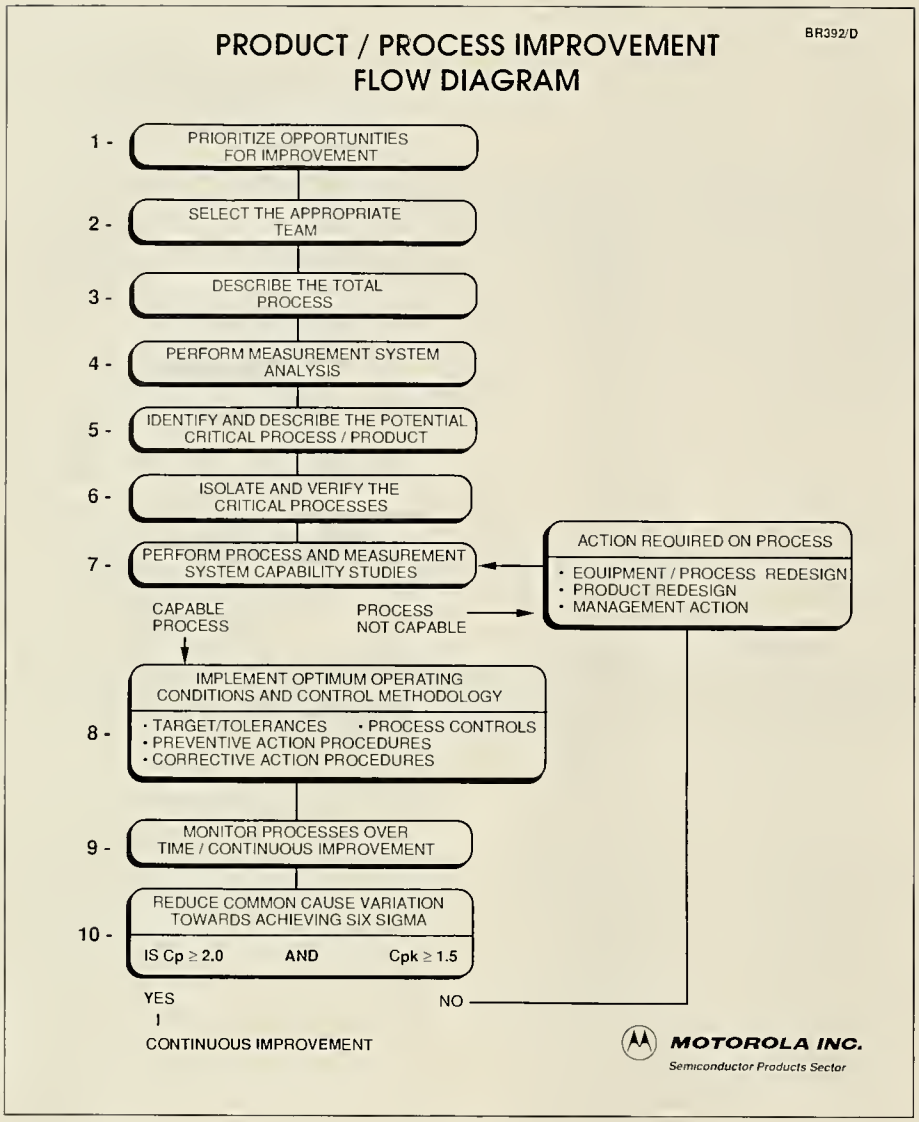
These companies make sure the field reports filed by sales and service people about their products—and the problems customers have with them—quickly get into the hands of designers, marketers and factory technicians, who just as quickly find solutions to those problems. This feedback loop assures that changes appear in a matter of days, instead of the months often required under the old, top-heavy system.

3. Fix the Process, Not the Problem

One of the underlying principles of TQM is that to create defect-free products and services—known as zero variation—you have to fix the process, not the problem, whether that process involves manufacturing, service or administration. Any company can fix a problem that crops up in its copier, computer, avionics component or contact lens, but by finding the cause of the problem and fixing it at its source, one can eliminate the chance that similar problems will arise in the future.

While the idea is simplicity itself, implementing it is not. Sometimes the problem in a process involves people, sometimes it stems from a poor work flow, sometimes it's due to inadequate measurement or statistical process control—sometimes it's everything. To fix a process one must use solid data and careful analysis. The bottom line in process improvement is reducing variation, which helps curtail the need for inspection —and correcting defects—at the end of the process.

Richard W. Anderson, a general manager at Hewlett-Packard, is often quoted in corporate training materials because he expresses this principle so succinctly. "The earlier you detect and prevent a defect," Anderson says, "the more you can save. If you catch a two-cent resistor before you use it and throw it away, you lose two cents. If you



COURTESY OF MOTOROLA INC.

Companies like Motorola have developed formalized procedures, left, for achieving continuous improvement. At Motorola, the ultimate objective is reducing variation in its products to the level of six sigma, below, or 3.4 defects per million opportunities.

don't find it until it has been soldered into a computer component, it may cost $10 to repair the part. If you don't catch the component until it is in the computer user's hands, the repair will cost hundreds of dollars. Indeed, if a $5,000 computer has to be repaired in the field, the expense may exceed the manufacturing cost."

4. Design Quality Into Products

TQM principles hold that many quality problems are the product of faulty design. Robust design is one way to overcome the limitations of traditional design methods. A robust design is one that takes into account the inherent limitations of a particular manufacturing process, but still produces a reliable product time after time.

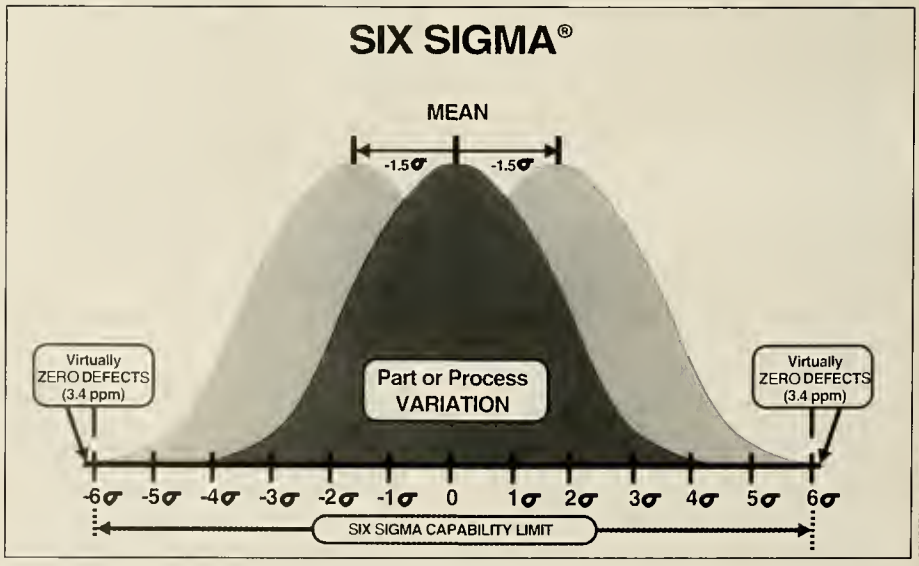
But quality designs are worthless if it takes so long to produce them that the competition gets its product to market faster. Concurrent engineering is a way of streamlining the design process and making it less wasteful of human energy.

Lew Veraldi, vice president of Ford Motor Co., who led the team that brought the Taurus to market, defined the problems of the traditional, serial design process: "What someone designs and styles may be quite another matter to engineering. And by the time it reaches manufacturing, there may be some practical problems inherent in the design that make manufacturing a nightmare. The people who actually build the vehicle haven't been consulted at all. And, marketing may well discover two or three reasons why the consumer doesn't like the product, and it is too late to make any changes."

In concurrent engineering, everyone who will make decisions about a new product gets involved from the start. Potential problems in engineering, manufacturing and marketing are identified at the beginning of the design stage, when it is less expensive—and time consuming—to correct them. And, by carrying on the processes of design, engineering, manufacturing engineering and marketing simultaneously, the whole thing goes much faster and products get into customers' hands in a fraction of the time needed under the old model.

5. Use the Right Statistical Tools to Reduce Defects and Boost Quality

To statisticians and industrial engineers, sigma (σ), the 18th letter of the Greek alphabet, means standard deviation, a measurement of the range of variation in an object or process. In the world of TQM, sigma—preceded by a number—has come to connote the concept of quality.



COURTESY OF MOTOROLA INC.

The higher the sigma number, the fewer the variations from specification and, therefore, the greater the quality. As William Wiggenhorn explained in a 1990 article in *Harvard Business Review*, "In plain English, six sigma translates into 3.4 defects per million opportunities, or production that is 99.99966 percent defect free. By contrast... five sigma is 233 defects per million, and four sigma is 6,210 per million opportunities."

Eliminating defects calls for some detective work. The first step is to make variation visible by gathering and analyzing data associated with the process. Then, through experimentation and careful tracking, one must find out what's causing the manufacturing process to produce too great a range of variation. Accomplishing these tasks requires sophisticated measurement and statistical tools and a work force trained to use them.

In fact, the ability to understand and use the tools of measurement and statistics is fundamental to total quality management. There are hundreds of statistical methods—commonly lumped together under the rubric of statistical process control (SPC)—that can be used in designing and optimizing processes and products. Millions of words have been written about these tools. For example, Motorola University, an educational subsidiary of Motorola, is compiling what will ultimately be an 18-volume, 7,000-page collection of statistical tools, case studies and literature called the *Six Sigma Owner's Manual.*

Once a company has realized a quality gain through the use of SPC, it is important that that accomplishment be codified in the form of a new standard, and that the road that led to the quality boost be carefully documented. If similar processes are used in other areas of the company, managers there must be told how they can realize similar gains in quality by conforming to the new standard.

6. Don't Limit the Pursuit of Quality to the Manufacturing Floor

The concepts that make it possible to better control the manufacturing process can also be employed to improve administrative functions like accounting, service, sales and shipping. Just as with manufacturing, one must collect data about how the process works, analyze the causes of the most significant problems and design a new system that offers less opportunity for error.

Is it worth it? Imagine an accounting office that typically records a million entries for its month-end closing. If the data it receives is 95 percent accurate, that means there will be 50,000 errors. Correcting those errors will cost money and lower morale. Instead of waiting to catch thousands of errors at the end of the process, a company can use SPC to seek out and eliminate the root cause of those errors, saving time, money and materials—and improving employee morale and customer satisfaction.

7. Make Sure the Commitment to Quality Starts at the Top

The alumni interviewed for this article agree that the person at the top must lead the TQM movement in his or her company; that responsibility cannot be delegated. Part of the struggle for senior management, they say, especially in the early stages of change, is balancing long-term quality goals against the short-term need for financial performance. If the company's top person doesn't make continuous improvement the highest priority, it simply won't happen.

Senior management must also make sure quality goals are linked to the strategic planning process. The chief executive officer has to "walk the talk," as they say in TQM circles. If he or she doesn't, then in the words of one quality manager, "don't even bother; find another job."

8. Clearly Tie Rewards and Recognition to Meeting Quality Goals

As any industrial psychologist will explain, people do what gets them rewarded. Many companies have found themselves midstream in a culture change, but still not making the progress they think they should. When senior management digs for the source of the problem, it often discovers that workers are still being rewarded for things that have little to do with quality. For example, in many companies rewards are tied to meeting shipping or sales quotas, even if that means sending out defective products or promising delivery dates that can't be met.

TQM companies often link rewards—especially promotions—to employees' adoption and use of quality tools and processes. Xerox, for example, has gone so far as to say

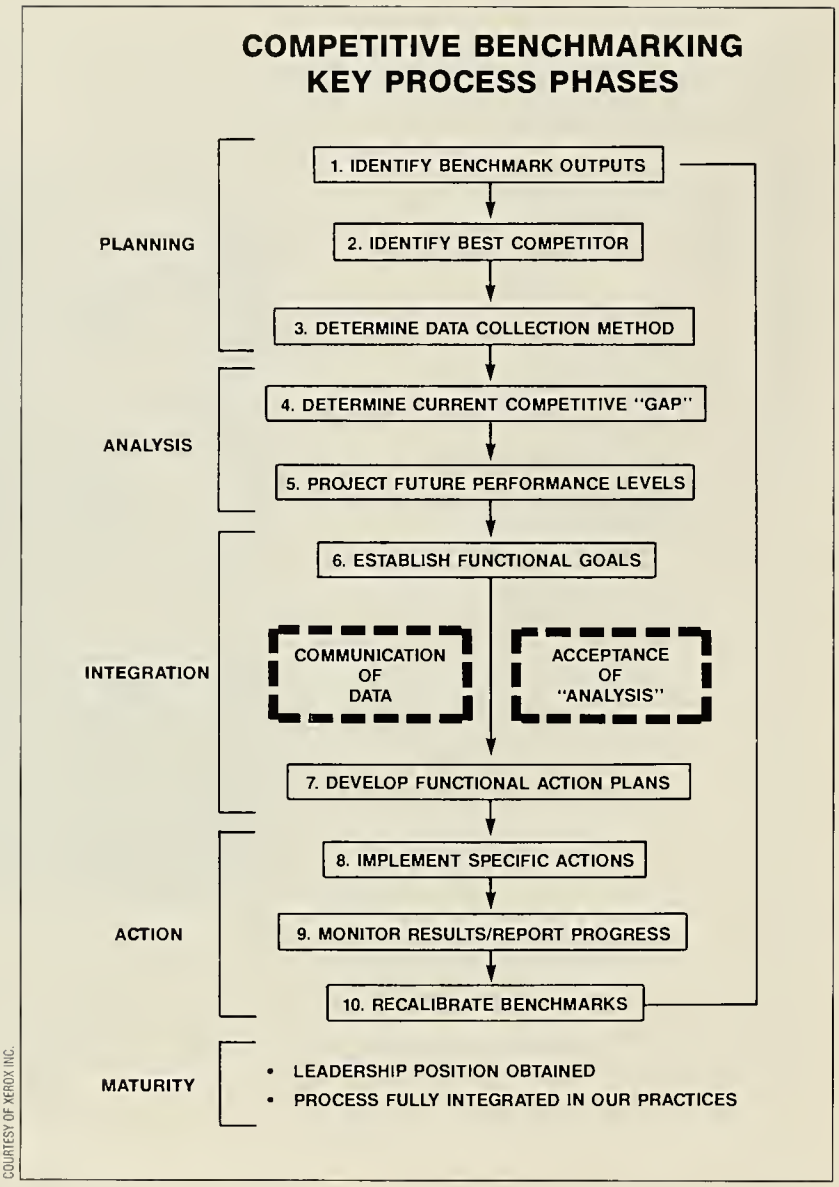
Competing for Quality's Biggest Prize

COURTESY OF MOTOROLA INC.

The Malcolm Baldrige National Quality Award was established by Congress in 1987 to promote quality awareness and encourage the development of successful quality strategies by recognizing the achievements of U.S. companies. Named for the late secretary of commerce, the award is administered by the Department of Commerce and the National Institute of Standards and Technology, with help and financial support from the private sector.

A company that believes itself to be a leader in total quality management may apply for the award in one of three categories: manufacturing companies or subsidiaries, service companies or subsidiaries, and small businesses. Up to two awards may be given each year in each category. Award winners agree to share their successful quality strategies with other U.S. organizations.

Applicants are judged on their performance in seven categories (see Communiqué, page 6), each of which is worth a specified number of points. A perfect score is 1,000. Written applications are evaluated by members of a board of examiners, and high-scoring applicants are selected for site visits. Award recipients are recommended to the secretary of commerce by a panel of judges from among the applicants who receive site visits. All applicants receive written assessments that summarize strengths and identify areas that can be improved. The American Society for Quality Control helps administer the examination process.



Xerox, like all TQM companies, benchmarks its performance in a wide variety of areas against other companies known to be leaders in those areas. As step 10 in this Xerox procedure indicates, benchmarks must be continuously updated.

that managers must achieve "role model" ratings in the implementation of its "Leadership Through Quality" philosophy. No role model rating, no promotion; it's that clear.

Another way to reward people is through recognition. At least once a year, most TQM companies have programs similar to a trade show that bring together teams that have made quality improvements to demonstrate their projects. Some companies, like Xerox and Motorola, invite external suppliers and customers. The programs give public recognition to successful quality efforts and stimulate still more.

9. Measure Your Performance Against the Best

Benchmarking, or comparing yourself to the competition, has been around in various forms for a long time. But some benchmarking efforts are better than others.

Benchmarking is more than comparing head counts or financial ratios. Any product or process can be benchmarked. The goal should be to benchmark one's procedures for making products or providing services against those of other companies that have reputations for doing an excellent job. Depending on what's being benchmarked, the companies chosen as yardsticks need not be industry competitors. Xerox, for example, benchmarked itself against American Express when it wanted to reduce customer complaints about billing.

It's important to remember that benchmarks have a limited shelf life. Markets and customer demands are constantly evolving, and a company's benchmarks must change with them. To be truly useful, benchmarks must be continuously updated.

10. Remember That Quality has Costs, Though Ignoring Quality is Costlier

There are two ways to look at the cost of quality: the price of conformance and the price of nonconformance. The price of nonconformance is the money a company spends doing things wrong. It includes the cost of labor and material to correct errors, rework defective products, process complaints and make repairs under warranty. It also includes opportunities lost because the marketplace doesn't trust you anymore.

The price of conformance is what it takes to make things right the first time. Experts agree that conformance is significantly cheaper than nonconformance.

11. Allow Enough Time for Quality to Take Hold

Some companies talk about the move to continuous improvement as a renewal; others call it a revolution. But they all caution that it takes time. Those who venture on this path have to be prepared for setbacks and failures. Some quality gurus say it can take 10 years to fully implement a TQM process in a large organization.

The concept of continuous improvement is profoundly conservative at the same time that it is immensely revolutionary. Its conservativism lies in its goal of making a company as competitive as possible within its marketplace, thereby increasing profits. That goal is as old as business itself.

But where TQM truly breaks new ground is in its rejection of the hierarchical corporate model so pervasive in industrial history. It replaces this entrenched concept with a model in which people at all levels of an organization have the power to make meaningful decisions about how best to serve the customer. For customers, the most revolutionary aspect of TQM may be the fact that they no longer need to enter the marketplace with the caution *caveat emptor*—buyer beware—foremost on their minds.

Diane Benison is a former newspaper editor who now works as a free-lance writer and editor and teaches journalism in Clark University's College of Professional and Continuing Education. She wrote about the Center for High-Performance Computing and the bioethics research of Thomas Shannon for the Summer 1992 WPI Journal.

Like the Phoenix, Xerox Rises From the Ashes of Failure On the Wings of Quality

By Diane Benison

In retrospect, Xerox Corp.'s story is simple. It had a technology breakthrough (the plain-paper copier) and cornered the copier market. It made enormous amounts of money and quickly grew to become a *Fortune 500* company. Then, because of a constellation of mistakes and miscues, including corporate arrogance and denial about the threat of competition, it squandered its market dominance.

In *Prophets in the Dark,* the book he wrote with management consultant David A. Nadler, former Xerox chairman David T. Kearns said that by the early 1980s he believed Xerox faced the real prospect of being a failed company sometime during the 1990s. As early as 1980, he wrote, "there was beginning to be a sickening self-doubt within the company that we were basically living on borrowed time."

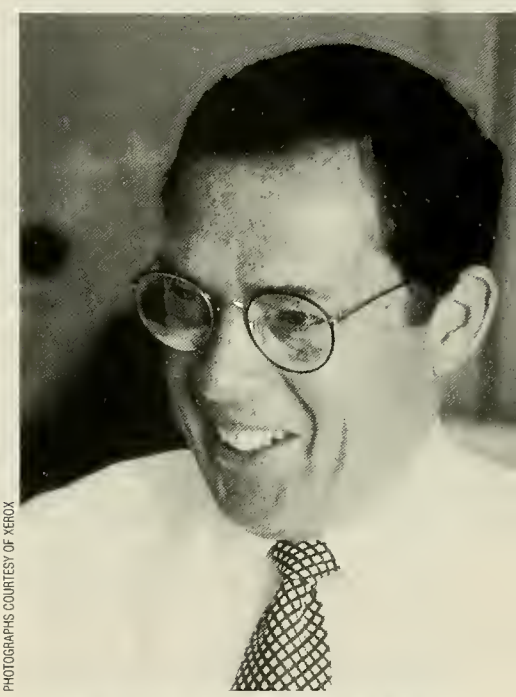
Happily for Xerox stockholders and its more than 100,000 employees, the company used that time wisely. Today Xerox has regained some of its market share and is a respected player, not only in its original market, but in the emerging "document" market. So strong has that turnaround been that a recent story in *The New York Times* described Xerox's Model 5100 copier as a "case study in how to beat the Japanese."

But few stories, particularly comeback stories, are simple or quick. Comebacks, especially on the scale achieved by Xerox, usually reflect painful introspection, recognition of a need to change and summoning of the will to make that change happen. Xerox needed to overhaul its corporate attitude and behavior. And, as Xerox employees who lived through that cultural change will tell anyone who'll listen, it required persistence, determination, patience, discipline and still more introspection. It is, they add, easier to say those things than to do them.

The doing, and the resulting cultural growth and maturation, is the real Xerox story. Xerox, which today calls itself "The Document Company," is now known for its philosophy of "Leadership Through Quality." Developing and defining that philosophy, instilling it in its employees, and training those men and women to make it inform their work each day, is what enabled Xerox to engineer its own turnaround. As Kearns proudly points out in his book, "Xerox did it without government subsidies, protective tariffs, or voluntary import quotas."

Paul A. Allaire '60, current chairman and CEO, has spent more than 26 years at Xerox and was part of the senior management team responsible for salvaging the company. Today Allaire, a WPI trustee, is leading Xerox through the next phase of its evolution into total quality management (TQM) by changing the "architecture" of the company. Having successfully spread quality messages and practices throughout Xerox, he is guiding the corporation through a new period of transition.

In terms of its impact on society, many observers compare the invention of the plain-paper copier to the invention of moveable type. Like the latter invention, the technology of plain-paper copying helped democratize the flow of information. That fact probably explains why the demand for copying machines was so great and grew so rapidly—much more than Xerox itself ever expected when its Model 914, the world's first plain-paper copier, was announced in 1959. Until the commercial introduction of the 914, copiers required special paper much like that used by most fax machines today.



PHOTOGRAPHS COURTESY OF XEROX

Now chairman and CEO, Paul Allaire helped engineer Xerox's turnaround.

The success of the 914 and the growth it set off caused some of Xerox's problems. By 1972 the company controlled 60 percent of the overall $1.7 billion copier market and 95 percent of the plain-paper copier market. In December of that year the Federal Trade Commission filed a complaint against Xerox for restraint of trade, charging, among other things, that Xerox illegally monopolized the market for copiers. As part of a settlement reached with the FTC in 1975, Xerox agreed to license its technology for plain-paper copying to other companies—including Japanese firms.

Once Xerox was forced to license its technology, competitors began to nibble away at its business, starting at the low end of the market. More significantly, after the FTC settlement, Japanese companies targeted Xerox and the copier industry. Xerox, by then a *Fortune 500* company, was

President Bush presents the Malcolm Baldrige Award to former Xerox chairman David Kearns.

earning a 19 percent return on assets, but that success had its price. The company had become arrogant. It felt unthreatened by the prospect of competition. Fiefdoms had grown up within the organization and their internal politics hindered cooperation. More serious, Xerox, in Kearns words, was making "inadequate products."

Between 1976, when the FTC settlement was handed down, and 1982, Xerox's share of U.S. copier installations dropped dramatically. As market share fell, so did profits. The layoff of thousands of employees as a cost-cutting measure did nothing to address the deep-rooted organizational and operational problems that beset the company during this period.

So Kearns, Allaire and the rest of the senior management lead a year-long revolution to change the corporate culture at Xerox. Their goal was to make the quality of Xerox products so good—and so responsive to customer needs—that the company would regain market share, profitability and return on assets. That conviction fueled the company's revival and helped win it the coveted Malcolm Baldrige National Quality Award in 1989.

How did Xerox do it? It was, in the end, the result of a number of relatively independent developments that occurred within the same period of time.

One of the first happened not at Xerox headquarters in Stamford, Conn., but in the countryside of Maine. In 1979, Robert Camp, an inventory control analyst at Xerox, decided to undertake a benchmarking project, determined to find a better way to handle distribution. He made a trip to L.L. Bean to find out how the company had achieved its reputation for excellence in wholesale distribution.

Camp discovered that Bean was using bar codes to label every item in its warehouse. In addition, its computer ordering program was written so that when a customer's order was printed and handed to a warehouse employee to be "picked," the items were printed in the same sequence in which they were stored in the warehouse, reducing the time needed to fill orders. The visit sold Camp on the value of benchmarking and he became an advocate for the practice within Xerox. Benchmarking was adopted companywide in 1981.

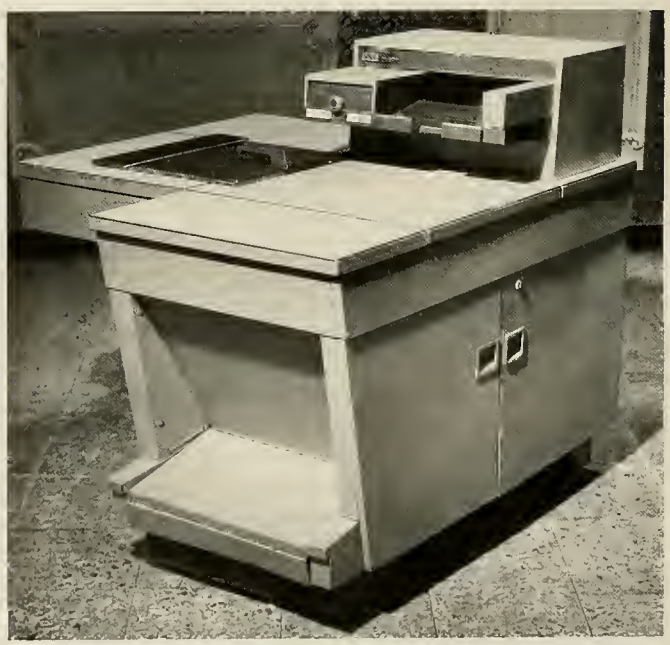
Kearns, meanwhile, had begun making trips to Japan to visit Fuji Xerox, of which Xerox was a partial owner. In 1980, when Fuji Xerox won the Deming Award, Japan's national quality prize, Kearns began to analyze the differences he saw between Xerox's Japanese and U.S. operations.

He also set up an internal team at Xerox to study the organization and recommend changes, and in 1982 he hired consultant David Nadler. The following February he took a major step: he organized and led a three-day meeting of 25 senior managers at the company's Leesburg, Va., training center. It was that group, which included Allaire, that developed the Leadership Through Quality process. Kearns had come to believe that the company would not change unless that change was driven from the top. The Leesburg meeting was his starting point. The rest is history.

Some of the things that helped bring about change at Xerox, including benchmarking and statistical process control, were not new when Xerox began using them. Xerox's most significant achievement was changing the way people worked together, the way they communicated with each other and the way they cooperated to solve problems.

Organizations, like individuals, have psychologies, although at the organizational level they are usually called corporate cultures. Until a corporate culture supports and encourages genuine employee involvement and communication—up and down the hierarchy and across functional areas—the use of quality tools alone will not achieve total quality.

Every business or institution that decides to move to a TQM process must change the way it thinks and the way it does business. Xerox made quality its basic business principle, and it spread that principle and a clear definition of what it meant throughout the company. Its mission



The success Xerox realized after it introduced the first plain-paper copier, the 914, in 1959 bred arrogance and complacency.

statement makes that clear: "Xerox is a quality company. Quality is the basic business principle for Xerox. Quality means providing our external and internal customers with innovative products and services that fully satisfy their requirements. Quality improvement is the job of every Xerox employee."

Xerox tells employees that its definition of quality differs from the "conventional view" in at least four respects:

"Whereas the conventional definition of quality reminds us of words like 'goodness' and 'luxury,' Xerox defines quality as conformance to customer requirements.

"Whereas the conventional performance standard for quality is some acceptable level of defects or errors, the quality performance standard in Xerox is products and services that fully satisfy the requirements of our customers.

"Whereas the conventional system of achieving quality is to detect and correct products after they have been completed, Xerox emphasizes the prevention of errors.

"Whereas the conventional system for measurement of quality relies on indices, Xerox measures quality by the costs we incur when we do not satisfy customer requirements."

Changing the attitudes and behaviors of managers and workers, as well as the way departments interact, is fundamental to TQM. By the time Kearns and his senior managers launched Leadership Through Quality, Xerox employees had become skeptics, if not cynics, as one senior management initiative after another quickly failed. Internally, Xerox employees referred to each new management proposal as the "flavor of the month." For a long time, Leadership Through Quality was seen as just another flavor that would soon be replaced by something else.

That attitude slowly changed as managers began to "walk the talk." It started with something called "cascade training." First, Kearns was trained in problem-solving and quality-improvement methods. He then led the training for the managers who reported to him—his "family group." Each member of that group, in turn, was responsible for training his or her subordinates.

Managers were assisted by professional trainers, but they were expected to do the bulk of the work themselves. The idea was to avoid the pitfall of managers sending their subordinates off to learn how to interact in new ways, only to have them return to the same old environment and the same old ways of doing things. In time, the lessons of quality cascaded through the organization and the rhetoric began to be backed by new behaviors.

Today, Xerox uses five mechanisms to assure that it stays on the path of continuous improvement. They are:

Standards and measurements: These include statistical tools, a six-step problem-solving process, a nine-step quality-improvement process, competitive benchmarking, an emphasis on error prevention and doing things right the first time, and techniques for determining the cost of quality.

Recognition and reward: Xerox encourages and motivates its employees to practice Leadership Through Quality by publicly recognizing and praising quality improvements. They range from a companywide quality day, where teams demonstrate their projects and discuss their achievements, to simple thank-yous and cash bonuses.

Communications: Xerox uses formal vehicles, such as magazines and films, and informal means, such as staff meetings, to talk about quality and meeting customer requirements and expectations.

Training: Xerox still uses the family-group approach to teach problem solving and quality improvement. That approach is designed to ensure that managers get involved in training their subordinates. Xerox calls this a "learn, use, teach, inspect" approach to reinforcing the quality improvement objectives of training.

Management: Xerox believes managers must set the example of using the quality-improvement process and problem-solving tools. Promotion at Xerox is tied to a manager's success at being a role model in the use of continuous improvement.

Xerox, like most other companies that have adopted the continuous improvement philosophy, has developed its own language and formal procedures around the process. The six-step problem-solving process and the nine-step quality-improvement process (see page 9) are examples.

Called a "case study in how to beat the Japanese," Xerox's new Model 5100 copier is a reflection of how the company has become more responsive to customer needs.

Xerox expends a lot of effort assessing how well it is meeting customer expectations and determining what customer requirements will be in the future. It sends out more than 40,000 surveys a month to customers; with a return rate of 35 percent, that's a lot of feedback. The results of each month's survey are distributed to all areas and unfavorable or neutral surveys get follow-ups. The goal is to use the surveys to find and fix systemic problems.

When asked how it is possible to make a company as large as Xerox more market-driven, Allaire cites an example of something the company does to keep employees focused on customers. "We start each of our internal meetings, no matter who we're with, by going around the table and asking, 'What have you learned from a customer since our last meeting?' Clearly, that sets an example, because it means all the senior people have to be out talking to customers," he says.

"It is somewhat symbolic, but it is important," he adds. "We have as much customer contact as we can possibly get. I visit customers on a continuous basis. We measure

Xerox's International Center for Training and Management Development near Leesburg, Va., is a centerpiece in the company's efforts to train its employees in TQM.

customer satisfaction more effectively, and focus more on the metrics of market share, than we ever have in the past. We spend a lot of our training for our technical community on what marketing means—what it means to be market-driven."

Xerox, Allaire says, has worked hard to change the company from a product-oriented focus to a real market-oriented focus. It has also worked to change the attitudes of engineers, who in the past have felt successful if they simply met the specs they got from the product planners. Now Xerox engineers understand that success is defined in terms of how well a product sells, how profitable it is, and how much value it creates for customers. "We're going to be a market-driven company," Allaire says. "We really use the customer to integrate everything we do."

With the recent reorganization of Xerox's copier and printer businesses, Allaire, who was named president of the company in 1986, CEO in 1990 and chairman in 1991, says he hopes to change the basic "architecture" of Xerox. "We have substantially changed the way we are organized," he says. "We have changed the company from a functional, vertical, fairly monolithic entity to one that is organized by divisions and teams within divisions. Now we have nine business divisions; within those divisions are 30-plus business teams, which really have accountability for their part of the business."

With the change, decision-making authority and responsibility have been pushed down to the nine new divisions. In addition, a new "corporate office" has been established, consisting of Allaire and five senior executives.

The reorganization should enable Xerox to take the kind of work that has been done within the company by cross-functional problem-solving and quality-improvement teams—work that helped Xerox implement its Leadership Through Quality process—and weave it into the fabric of daily operations and decision making throughout the corporation, Allaire says.

The way Xerox went about planning this latest change is indicative of how communications within the company have changed as a result of continuous improvement. The company made no secret of its plan to reorganize and restructure the business. The two teams that labored over the course of 15 months to develop the new structure did so openly. As a result, Allaire says, by the time the new plan was put in place, "there was already a lot of buy-in."

This was more than an exercise in rearranging the boxes on an organizational chart, Allaire says. It was an effort to develop a team environment where business decisions can be made based on customer requirements. He stresses that the new organization is not designed to be static. "We designed it so that it can flex, so it can change as the market changes," he says.

Allaire says he is optimistic that the company, having won the Baldrige Award and a new market recognition for its quality products, will not become complacent. "We have bright, capable people," he says. "They're well-motivated. We have no lack of challenges, so we have no need to become complacent. There are also enough of us around who know how large a price we paid for our complacency in the 1970s. Nobody from that era is ever going to become complacent again."

Midwives to Change

The story of how alumni at Motorola, Bausch & Lomb, Hamilton Standard and Polaroid Helped Bring TQM to Their Companies

By Diane Benison

Just as every couple with a new baby has a personal story to tell about its arrival, every firm that aspires to become a TQM company or makes the transition has its own, unique tale about the birth of its continuous improvement program.

Many of those stories have already been told in books, business school case studies and articles in publications like the *Harvard Business Review.* What follows are brief glimpses into the very different experiences of four major corporations that have successfully implemented quality programs or are in the process of doing so. These stories are told through the eyes of WPI alumni who have been at the center of those changes.

Motorola Finds There are Special Challenges to Implementing TQM in an Administrative Area

Motorola started its journey down the quality road in the late 1970s when Robert Galvin, then CEO, launched two efforts aimed at educating the company about new statistical tools and new technology. His efforts, however, did not produce the results he wanted. The basic problem, as many companies have learned, is that new tools and technology don't automatically engender new ways of thinking and doing, especially if they threaten the tribal customs that are inevitably part of every organization's culture.

Out of Galvin's frustrations came the Motorola Executive Institute, a one-time course for 400 executives "that tried to give them an M.B.A. in four weeks," William Wiggenhorn wrote in a 1990 issue of *Harvard Business Review.* "The participants learned a great deal, but again, the ultimate results were disappointing."

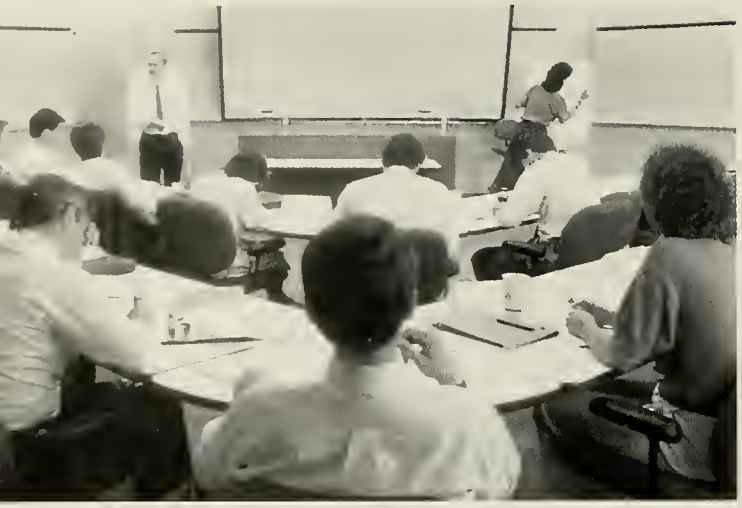
But in that disappointment were the seeds of fundamental cultural change. Galvin's next move was to set up the Motorola Training and Education Center (MTEC). It had its own board of directors that included Galvin, two of his top executives and senior managers from every Motorola operating unit. The center's goals, Wiggenhorn, the center's president, wrote, were "to expand the participative management process and to help improve product quality tenfold in five years."

While MTEC, or Motorola University, as it is also known, would emphasize retraining workers and redefining jobs, its main goal was to change attitudes and behaviors. It did this with a five-part curriculum that included courses on using statistical process control, solving problems, presenting conceptual material, running effective meetings and setting goals.

But as Motorola learned in the early 1980s, telling employees that there is another, more effective way to work is not enough; they must be motivated to change. So the company focused its attention on finding ways to create that motivation.

"In the end, we had to let people know that 'poor performance' included an unwillingness to change, and was grounds for dismissal," Wiggenhorn wrote in that *Harvard Business Review* article. "We had to abandon paternalism for shared responsibility."

As that message began to filter through the organization, Motorola discovered that workers and middle managers who were trying to apply the lessons they learned in training programs were too often frustrated by senior managers who failed to reinforce that training with a genuine new emphasis on quality.



A training session under way at Motorola University.

MTEC asked two universities to study the problem and evaluate the company's return on the money it was investing in training. The studies found that in those plants where the work force absorbed and used the statistical tools and process skills—and were reinforced by senior managers—Motorola realized a $33 return for every dollar spent. Plants where workers used either the statistical tools or the process skills—but not both—and were reinforced by their superiors, broke even. Plants that taught all or part of the curriculum, but did not reinforce it, had a negative return on investment.

Galvin decided the best way to get the message across to senior management was to shift the emphasis to quality at operations review meetings. Wiggenhorn reports that Galvin "insisted that quality reports come first, not last, on the agenda, and then he left before the financial results were discussed."

Galvin's success in changing the focus and behavior of senior management was the catalyst that pulled everything together at Motorola. The company's success in making the change was confirmed when it became one of the first winners of the Malcolm Baldrige National Quality Award in 1988.

One of the lessons Motorola has learned in its quest for quality is that it is easier to apply the tools of TQM (the company calls it Total Customer Satisfaction or TCS) on the factory floor than in an administrative area, according to Theodore J. Jaros '54, vice president and director of services and planning, world marketing, in Motorola's Semiconductor Products Sector.

"As you get outside of the factory, one of the questions you face is how to measure quality," says the 25-year Motorola veteran, who supervises a 175-person work force that is split evenly between serving internal and external customers. "First, you have to define the best metrics that will contribute, in a meaningful way, to continuous improvement."

Asked how progress is measured in his area, Jaros quips, "I wish I had the final answer to that. We're still in the process of evolving." But he says he does have some progress to report. One of the groups that reports to Jaros is responsible for distributing literature about Motorola products and parts via an electronic network. To measure the sigma level of its performance (see page 10), the group established goals for the time it should take to respond to requests for information.

Another group works with customers to design application-specific integrated circuits. After it has completed a project, the group asks the customers to evaluate various aspects of its performance, including their satisfaction with the technical aspects of the work and with the group's response time. The answers are then translated into numbers that can be analyzed and used to evaluate the group's response to customer needs.

For those who work in administrative areas, Jaros says one of the most useful applications of continuous improvement is called process mapping. In this technique, employees are trained to use quality tools to map a work process, figuring out each step needed to complete a task. They then determine which of those steps add no value to their work and eliminate them, reducing opportunities for error and shortening the time needed to complete projects.

How Bausch & Lomb's International Division Meets the Demands of Customers in More Than 100 Countries

Bausch & Lomb's International Division has 5,000 employees who speak more than 15 languages and work in 30 countries. They man 15 manufacturing plants around the world, making products that are sold to some 200,000 customers in more than 100 nations. Trying to make quality part of the corporate culture in an organization with that structural breadth and complexity presents significant challenges, according to division president Ronald L. Zarrella '71, a WPI trustee.

Zarrella, who holds the additional title of executive vice president of Bausch & Lomb, says the concept of TQM, or Total Customer Responsiveness (TCR), as it's known within the corporation, is not well-developed in many of the countries where his division does business. In particular, he says he and his senior managers must do basic "missionary work" to explain TCR to customers and employees in some of the lesser-developed countries where Bausch & Lomb operates. "To make this successful you have to

(Continued on Page 20)

TQM has helped Bausch & Lomb be more responsive to customer needs worldwide, says Ronald Zarrella.

How WPI's Management Department Practices What It Teaches

Helen Vassallo and Enio Velazco are helping the Management Department adopt a total quality program.

There's an old saying that those who can't do, teach. The men and women who constitute WPI's Management Department are working hard these days to show that when it comes to total quality management, they can teach *and* do. Having already developed courses that introduce students to the latest approaches to organizational management, the department is now putting those techniques to work to better manage its own efforts.

Assistant Professor Enio E. Velazco is one faculty member who has managed to not only teach the tools of TQM, but to use those tools to become a better teacher. In particular, Velazco, who has been teaching TQM for five years, says he applies the principles of continuous improvement and focusing on customer needs to his work in the classroom.

For example, after teaching a course on quality planning and control for the first time, he changed the emphasis and imposed stricter math prerequisites based on feedback from his on-campus customers (students) and off-campus customers (prospective employers of WPI graduates). Since then he has expanded his continuous improvement efforts by talking to recent graduates about how well the course prepared them for the world of industry.

Velazco says the department is also trying to benefit from the concept of cross-functional management, an element of TQM that emphasizes cooperation among departments within a company to the benefit of the entire organization. As an example, he cites a recent $10,000 grant from General Electric Co.'s Continuous Improvement Education Fund, which will support the development of a new graduate course in total quality management.

The researchers on the project represent two academic departments. Along with Velazco, who is the principal investigator, they include Assistant Professor Michael B. Elmes from management, and Professor and Associate Department Head Richard D. Sisson and Assistant Professor David C. Zenger from mechanical engineering. Velazco has also formed an informal advisory board of 22 quality professionals from business and industry. Their role, he says, is to provide "peer review" of the syllabus.

Because of its mission of teaching the latest techniques in organizational management, the Management Department often finds itself at the center of campus discussions about TQM, notes Helen G. Vassallo, professor and department head. She says those discussions have "been a bridge for us to collaborate on research and teaching efforts across departmental lines."

One development that helped make that bridge stronger, Velazco adds, was the creation within the Management Department of the Center for Productivity and Quality Improvement. Launched in March 1991, the center is part of the department's pilot program for implementing TQM in an academic environment. The center's mission, he says, is "to provide a focus for faculty activities in management involving teaching innovation, scholarship and sponsored research."

One of the most basic questions Vassallo and her colleagues have had to grapple with is just what quality means in an academic setting. The management faculty have tackled that question, as well as how to apply the principles of TQM within the department, at annual retreats.

"At the 1990 retreat," Vassallo says, "we decided to focus on the issues of innovation, entrepreneurship, productivity and quality improvement. Afterward, people began to have brown bag lunches to talk about how to deal with these issues." One of the results was an increased emphasis on interdepartmental teaching and research. Velazco's General Electric grant is one outgrowth of that emphasis.

After a retreat in 1991, the department began to consider its own goals in the context of the six goals of the Institute's strategic plan. The product of those discussions is a "road map," still under development, that will guide the department in its quality efforts. The map begins with the department's mission statement, from which stem several specific goals. Strategies are being developed for achieving each goal. From these will arise lists of concrete actions that must be taken to implement the strategies. The final step will be assigning those actions to individual faculty members and determining how many new resources, if any, will be needed to carry them out.

Vassallo says she knows the road map is only a start. Like many of the companies that have implemented TQM programs, the department will likely revise this plan many times as it is put into action. But Vassallo says she hopes that the ideas in the map will become a model for a true culture change at WPI. In fact, the department has developed a similar road map concept for the entire college that will help guide the efforts of the new Blue Ribbon Task Force as it plots out new directions and goals for the Institute.

Employees share successful ideas at a Bausch & Lomb quality day.

(Continued from Page 18)
keep a high level of corporate involvement —that's me," he says.

One of the competitive advantages TCR has given Bausch & Lomb is a reputation for paying attention to customer needs. "We were always known for high-quality products and technological leadership," Zarrella says, "but we weren't so good at listening to customers."

Listening to customers is especially important for Bausch & Lomb, as its product line includes sunglasses and contact lenses. Since ideas of beauty and fashion vary from country to country, products designed and made for customers in the U.S. won't necessarily meet the cosmetic or functional needs of consumers in other countries. TCR helped Bausch & Lomb begin to recognize the importance of those differences, Zarrella says.

The International Division has done considerable training on the principles of understanding and responding to customer needs. As a result, the division, which won the Bausch & Lomb President's Quality Award in 1990, has been able to document significant increases in customer satisfaction with its products and services. But Zarrella says he thinks his division will get its best leads on how to respond to customers by asking noncustomers why they don't buy Bausch & Lomb products, something it started to do this year.

"The underlying premise of TCR is that only the customer can provide the direction for enduring success," he adds. And for Bausch & Lomb, which posted revenues in 1991 of more than $1.5 billion—of which more than 45 percent came from regions outside the United States—keeping its worldwide customers satisfied adds up to a significant competitive advantage.

Hamilton Standard Embraces Quality to Bolster its Competitive Stance in a Changin

Like many other companies, Hamilton Standard, a division of United Technologies Corp., turned to TQM after a painful experience. By late 1986 it had lost more than $100 million and was the focus of a comprehensive government audit that identified many quality- and system-related problems at the maker of aerospace systems, components and services. The audit would eventually show that problems in the areas of product quality, cost control, timely deliveries and customer satisfaction needed immediate attention.

In early 1988 the company's senior managers, sobered by the red ink and the federal audit, decided to act. They began by looking at companies like Xerox, Motorola and IBM that had successfully adopted the total quality philosophy. They came to the conclusion that Hamilton Standard needed a major culture change; by September 1988 they had hired a consulting firm to help them achieve it.

Early in the process, these 15 executives went through eight days of training to learn about continuous improvement and how

Hamilton Standard's Gordon Sigman Jr.

Hamilton Standard might implement it. During that 1988 training session the company's first vision statement was developed and the firm committed itself to emphasizing teamwork, consensus build-

For Polaroid Corp., Implementing a Continuou Has Meant Top-to-Bottom Change

In some ways it's not surprising that Joseph J. Kasabula '68 is in his present position. He says he first began to think about the nature of quality when he was a student at WPI. Those thoughts were aroused one day in chemistry class when the professor read a quote by noted 19th century English art critic John Ruskin. "Quality is never an accident," Ruskin said. "It is always the result of intelligent effort. There must be the will to produce a superior thing."

Kasabula says those words have stuck with him. Today he puts that philosophy to work as quality strategy manager for product development and worldwide manufacturing at Polaroid Corp. in Cambridge, Mass. He is one of several quality ownership executives working to bring Polaroid's management process, which combines total quality concepts and tools with its own employee ownership concept (Polaroid is 20 percent owned by its employees), to the company that is most famous for its invention of instant photography.

As far back as 1982, Polaroid had begun to gain experience with statistical engineering and process-control tools. By 1990, when the company was aligned around four business units (Family Imaging, Business Imaging, Technical and Industrial Imaging, and Electronic Imaging), it was also beginning to develop a companywide process called Total Quality Ownership or TQO.

The original TQO design team was formed in September 1989; Kasabula joined it three months later. The team began by looking at 11 large companies that had already started continuous improvement programs. In September 1990 training in what Polaroid has called Quality Strategy started at the top when Polaroid CEO I. MacAllister

erospace Industry

ing, process improvement, employee ownership, employee development and customer focus.

Like other companies, Hamilton Standard has found that it takes considerable time just to complete the initial training of its employees. By mid-1992, though, more than half of its 9,500-member work force had been taught to put the tools of continuous improvement to work in their jobs. All manufacturing and factory employees are also being trained to achieve a basic competency in statistics and manufacturing process analysis.

One of the major goals of the culture change set in motion by Hamilton Standard is to develop a more proactive way of operating. "We value solving problems; what we need to value more is solving problems before they occur," the company tells employees in an internal publication. "Continuous improvement requires a culture change away from autocratic to participatory management. If we really desire to value people, then we must practice participatory management. People closest to the work must have the authority to make decisions based on a shared understanding of the company vision."

According to Gordon H. Sigman Jr. '59, vice president and general manager at Hamilton Standard and a WPI trustee, U.S. companies still dominate the world's aerospace business. "But you can see the Europeans and the Japanese are working hard and these guys are going to be capable competitors. If you go back to the early 1980s, you had a technology discriminator, but things have a way of equalizing." Sigman says the competitive battlegrounds of the future will be quality, reliability, price and the ability of companies to support their products.

Hamilton Standard, Sigman says, is now committed to a "total understanding of customer needs." The company, which hopes to be a serious contender for the Malcolm Baldrige Award in 1994, has conducted Baldrige-like assessments of its progress to date. The results of those assessments—the good and the bad—are shared with employees through regular newsletters.

While there are still pockets of autocratic management within Hamilton Standard, more than three years of effort has paid off, Sigman says. Despite the fact that the company is still training its work force, it has realized documentable improvements in customer service. These include greatly reduced turnaround times for repairs and service (from an average of 117 days to eight) and equally dramatic reductions in products returned due to defects.

Hamilton Standard's road to total quality has been especially challenging, given the fact that its efforts have coincided with a downturn in the U.S. and world economies. Tough economic conditions and related job instability can be serious obstacles to continuous improvement.

To compensate for these added challenges, Sigman says the company is working harder to make sure recognition for quality is consistent and public. Sometime next year that effort will get a boost when the performance and merit review systems are changed to reward managers and employees who focus on continuous improvement.

nprovement Program

Booth and several senior managers attended a four-day seminar developed and arranged by Kasabula. The three-ring binder that held the reading materials for that seminar weighed more than seven pounds.

Led by a team of quality strategy experts that included Bradley T. Gale '64, managing director of the Strategic Planning Institute at MIT and a member of the board of overseers for the Malcolm Baldrige Award, David A. Garvin of the Harvard Business School and Don O. Clausing of MIT, that group of senior executives covered a lot of ground. They started with the basics —the philosophies and approaches of three of America's original quality experts, W. Edwards Deming, Joseph M. Juran and Philip B. Crosby—and moved on to the elements of Quality Strategy.

Polaroid's TQO program was formally launched in the winter of 1991 when Booth held a series of 11 meetings with the company's top 200 executives. By the end of 1991 nearly all 8,000 U.S. employees had participated in initial training in the concepts of TQO. This year the initial training was adapted and given to employees of international subsidiaries, as well.

Joseph Kasabula of Polaroid Corp.

Also this year, Polaroid began pilot programs for an effort called TQO Action, which is aimed at helping business improvement teams select, analyze and solve problems in their work areas. Having studied how other companies have implemented total quality and ownership programs, Polaroid is using a pilot approach—blending work and learning processes, testing them on small groups, revising them based on feedback, and then using them on a companywide basis.

One of the characteristics of a company beginning to make the change to a total quality environment is that information about what's happening around the organization begins to flow in ways it never has before. For some managers that can be unsettling. As Kasabula observes, "As Total Quality Ownership moves into the organization, you have to relax. Things seem to get worse, but really what's happening is you're getting far more information than you ever have before. I think this has been *the* learning experience of 1992 for us."

Fall Madness

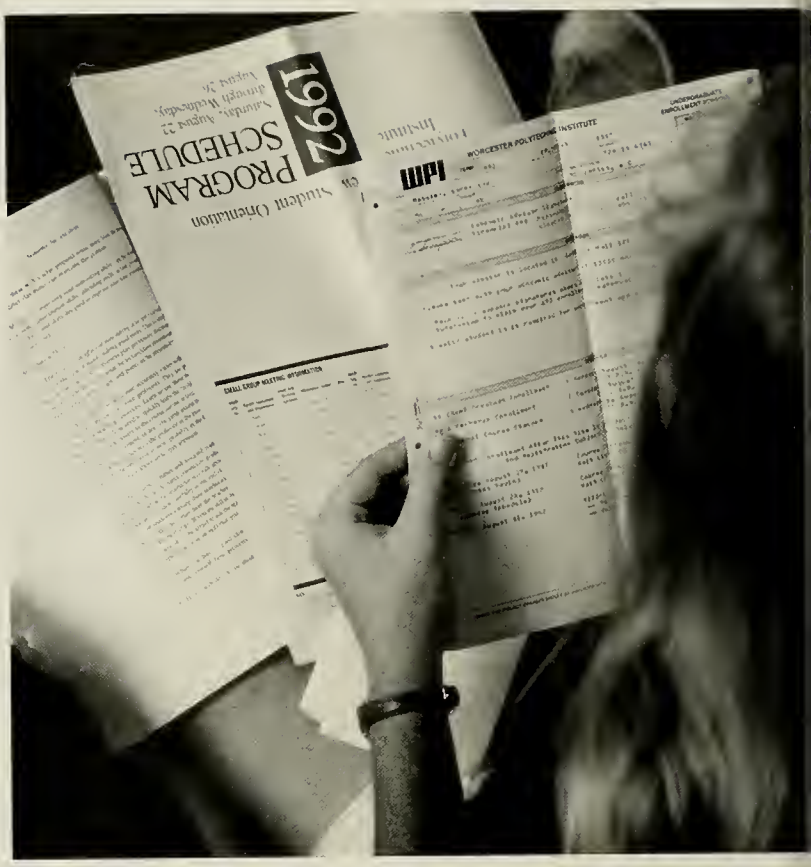
Each spring after classes have ended and Commencement is a pleasant memory, the WPI campus settles into a quiet but purposeful calm, not unlike the tranquility parents experience after sending their young children off to school for the day. With the pace of day-to-day life slowed, there is time to make repairs, update records, paint walls, mow lawns, attend conferences, and spend more time in the lab doing research.

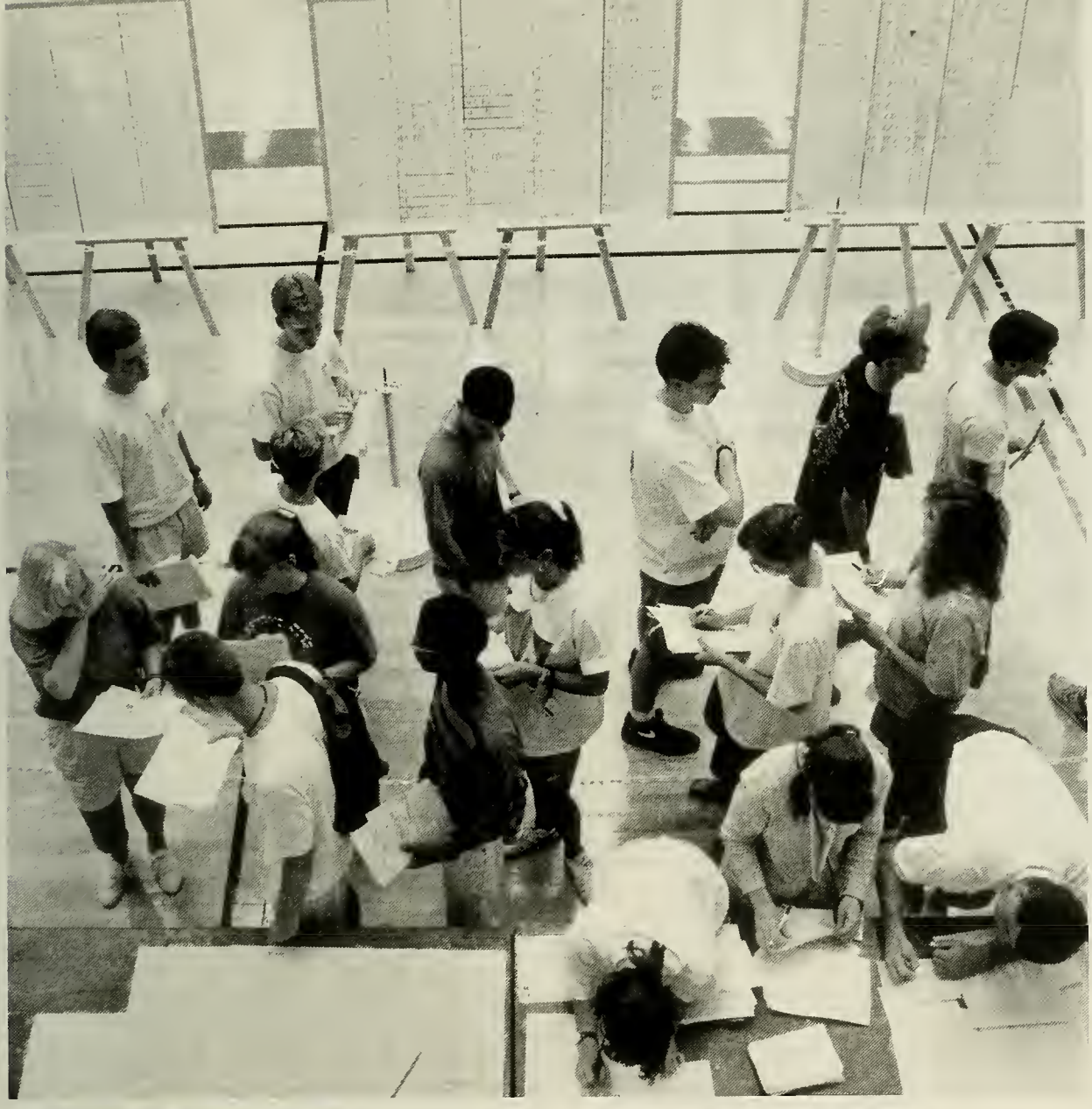
But then, one day in late August, the summer calm is shattered in a flurry of vans, trucks and U-Hauls bringing a new crop of freshmen and their parents to town for the start of another school year. It's the beginning of Fall Arrival, a weeklong marathon in which hundreds of undergraduates move into the residence halls, more than 600 freshmen get a thorough orientation to the campus and to the challenges and rewards of college life,

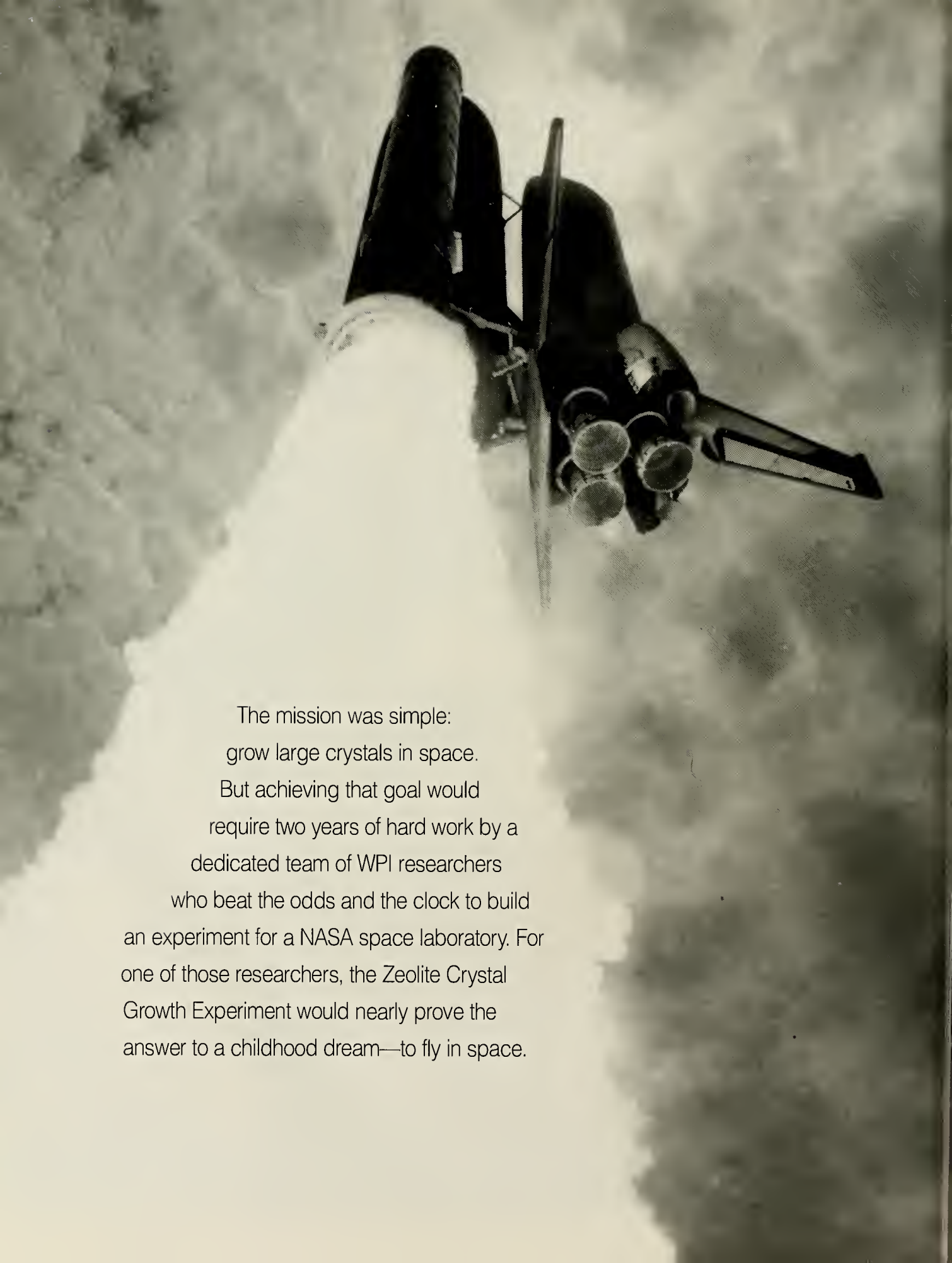
Photos by Janet Woodcock
Text by Michael Dorsey

anxious students flock to Harrington Auditorium to sign up for courses or make course revisions, smiling faces appear before cameras to be recorded on ID cards, and young men and women—course schedules in hand—scout the bookstore for the latest tomes on electrodynamics, fluid mechanics, calculus and the modern American novel.

It is a time that reminds every member of the WPI community—should they have forgotten—just why it is they come to work each day. For it is the students and their hunger for a superior education that form the motive force that drives the Institute's well-oiled machinery. So integral are these young men and women to the life and cadence of the college that, once the annual fall madness is over and the classrooms hum once more with the electricity of learning, and the dining halls ring with the clatter of plates and the chatter of young voices, and the athletic fields come alive again with the raw energy of competition, it is hard to believe they were ever really gone.







The mission was simple:
grow large crystals in space.
But achieving that goal would
require two years of hard work by a
dedicated team of WPI researchers
who beat the odds and the clock to build
an experiment for a NASA space laboratory. For
one of those researchers, the Zeolite Crystal
Growth Experiment would nearly prove the
answer to a childhood dream—to fly in space.

A Stellar Achievement

By Michael Dorsey

They're barely one-hundredth of a millimeter on a side, these perfect little cubes; to get a good look at one you need an electron microscope. They're made from a simple combination of three of the most common elements on Earth. Yet to a team of researchers in WPI's Chemical Engineering Department, these tiny objects are more precious than gold.

This rare booty is a collection of zeolite crystals manufactured in space, where the absence of gravity enabled them to grow much larger and more perfect than zeolites typically grown on Earth. They are the product of an experiment conceived and designed by WPI researchers and built by engineers and technicians from two major American engineering firms.

The experiment was part of one of the most extensive and successful science missions ever flown aboard an American spacecraft, the first United States Microgravity Laboratory (USML-1), which was carried into orbit by the space shuttle *Columbia* this past June. For the WPI team, the flight culminated two years of hard work that would ultimately bring national recognition to the Institute. They were years that would also lead one of those researchers to the brink of space itself.

For WPI, the road to USML-1 began one evening in 1983 in a small restaurant near the WPI campus. Over pizza and beer, Albert Sacco Jr. and the late Leonard B. Sand, colleagues from the Chemical Engineering Department, chatted in the easygoing manner of co-workers who have also become good friends.

At 61, Sand was one of the world's most respected researchers in the field of zeolites. Educated as a geologist and mineralogist, he had worked for Standard Oil and taught at the University of Utah before taking a position at Norton Co. as chief of a research and development unit creating synthetic zeolites. Made of alumina and silica, zeolites have a highly uniform network of microscopic pores that make them useful as molecular sieves and catalysts in a variety of chemical industries—especially petroleum refining. About 40 varieties of zeolites occur naturally; most now used in industry are synthetic varieties.

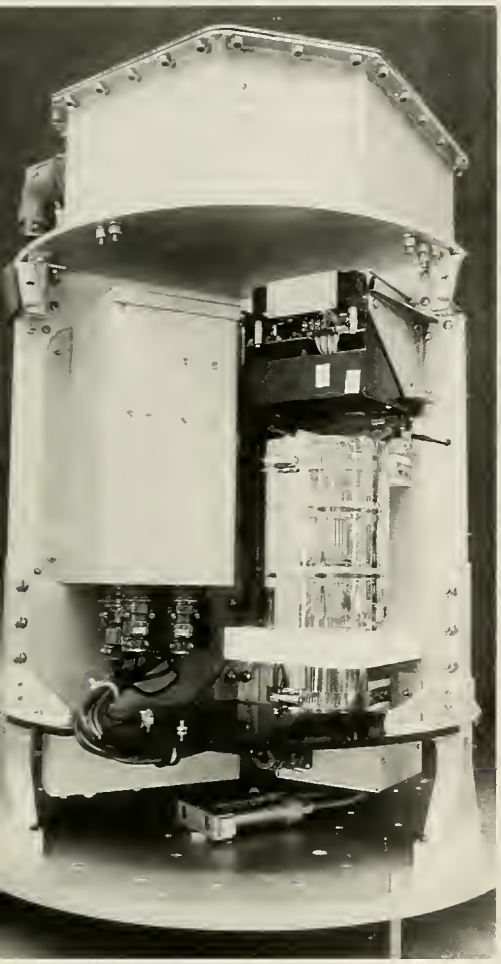
In 1967 Sand left Norton to join WPI, where his enthusiasm for the seemingly mundane zeolites convinced other faculty members to join him in learning more about how they work and how to make them better. In time the Institute developed the largest zeolite research program of any U.S. university.

On that evening in 1983, Sand hoped to get Sacco excited about zeolites. Then as now, Sacco's research focused on catalysis and solid-gas reactions. But growing up in the 1960s, he had also developed a keen interest in space (see Advance Word, page 2). Sacco made a deal with Sand: if they could find a way to combine Sand's research with Sacco's fascination with space, he'd join the team.

That intersection would be a student project to design and build a zeolite crystal growth experiment that flew on a space shuttle in June 1991 as part of a package of student-built hardware sponsored by MITRE Corp. The experiment was designed to test the hypothesis that, free from the pull of gravity, zeolite crystals will grow to unprecedented sizes.

Checking the literature, Sand and Sacco had learned that the largest natural zeolites are found in ancient lake beds. These irregular, impure crystals grew gradually over the course of centuries while chemical nutrients slowly diffused around them. In the laboratory, zeolites grow in thick, milky "gels" formed by mixing alumina and silica solutions. Heated in metal autoclaves, the crystals grow rapidly, reaching their maximum size in a matter of days.

"On Earth, the zeolites settle out of solution and you get a cake of crystals at the bottom and an essentially clear liquid at the top," says Robert W. Thompson, professor of chemical engineering. As the crystals settle, he



JANET WOODCOCK

WPI's first venture into growing zeolites in space was this student-designed experiment, which flew on a space shuttle in 1991. But the experiment sat on the ground too long, yielding poor results.

notes, growth subsides and then stops. By using techniques that control nucleation (the process by which crystal growth begins), Sacco and other WPI researchers have produced crystals substantially larger than those typically used in industry. But no matter how careful, every zeolite grower eventually runs up against the effects of gravity.

"Len and I knew that if you could suspend a crystal indefinitely and bring a nutrient stream past it, it would continue to grow," Sacco says. What better way to do that, they reasoned, than by moving the whole process into space.

Len Sand died in 1985, just two years after that conversation over pizza and beer. When Sacco looks back over what's transpired in the intervening years, he is quick to credit Sand with many of the insights that made those achievements possible. As a reminder of those contributions and of the friendship they shared, Sacco, who became head of the Chemical Engineering Department in 1989, keeps Sand's photograph in a prominent spot on his office wall.

While advising the students developing the space-based crystal-growth experiment, Sacco began giving talks at professional meetings on growing zeolites in space. One such talk, before a conference of the Society for the Advancement of Material and Process Engineering, brought him to Seattle in 1985. In the audience that day was William Jameson, an engineer from Grumman Corp. who had been hired by NASA to evaluate potential research focuses for the agency's efforts to exploit the commercial potential of space.

"He thought zeolites had a lot of promise and believed NASA should push ahead with that area," Sacco says. "As a result of that lecture and a meeting we had with Jameson, NASA chose zeolites as one focus."

Because of its reputation in the zeolite community, WPI was chosen by NASA as a founding member of the Clarkson University Center for Commercial Crystal Growth in Space, one of several centers formed around the country in 1986 to lay the groundwork for space commercialization. Later, WPI was also invited to join the NASA-funded Battelle Advanced Materials Center in Columbus, Ohio, where researchers were interested in finding ways to process catalysts in space.

As a member of the Clarkson and Battelle centers, WPI has received more than $3 million over the past five years from NASA and commercial sponsors to develop a zeolite growth experiment for the first United States Microgravity Laboratory, a 23-foot-long cylinder designed to fly in the cargo bay of the space shuttle. USML-1 was expected to be a showcase for American microgravity research in crystal growth, fluid dynamics, combustion, biotechnology, "astroculture" and space medicine.

Before designing the Zeolite Crystal Growth Experiment (ZCG), the WPI research team, which included Sacco, the principal investigator, and chemical engineering professors Thompson and Anthony G. Dixon, had to solve a number of problems, most of which revolved around the challenge of taking a process developed over many decades to work well in gravity, and making it succeed when gravity was no longer a dominant force.

"In space, secondary forces become dominant," Sacco says. "Instead of gravity-driven convection, you get concentration- or temperature-driven convection. You also get situations in which one liquid phase pulls away from another due to differences in surface tension."

These secondary forces threatened to thwart a fundamental requirement of zeolite synthesis—the need to start with a uniform, well-mixed gel. "The makeup of the gel determines which zeolites you get," Sacco says. "If you don't mix the solutions homogeneously before the gel sets up, you get the wrong silica/alumina ratios—which means you get an uncontrolled mess."

To overcome these problems, one can mix the solutions on the ground before launch. This is what Russian and European scientists have done; it was also the technique chosen for the WPI student experiment. Unfortunately, zeolite crystals begin forming soon after the two solutions are mixed. Chemicals can be added to delay crystal formation until after the experiment is in orbit, but these don't always work. And if the launch is delayed, the experiment can be ruined, as the WPI team well knew. While the mixture used in the student experiment was stabilized for about three weeks, the experiment sat on the ground for more than three times that long. "We knew we were in trouble right from the start," Sacco says. "The hardware worked fine, but the crystals were garbage."

The WPI team decided its solutions would have to be mixed in orbit, but learning how to do this would prove no small task. The Space Projects Laboratory on the second floor of Goddard Hall became a hotbed of fluid dynamics research as Sacco, Dixon, Thompson and a team of graduate students and postdoctoral fellows developed techniques to overcome secondary forces and produce a uniform gel. To fine-tune the techniques, Sacco took test autoclaves aboard NASA's KC-135. Nicknamed

NASA PHOTO

Sacco, right, and fellow APS Joseph Prahl test zeolite autoclaves on a KC-135 flight.

the "vomit comet," the plane provides brief periods of microgravity as it flies through a roller-coaster-like sequence of parabolas.

As a final check of their ideas, Sacco convinced NASA to add an experiment to the tightly structured timeline for USML-1. In it an astronaut would manipulate 12 clear-plastic autoclaves inside a glove box, testing several mixing schemes to see which produced the most uniform solution.

NASA PHOTO

The crew of USML-1 pose before the space shuttle *Columbia*. Front row, left to right, payload commander Bonnie J. Dunbar, mission commander Richard (Dick) N. Richards and pilot Kenneth D. Bowersox. Back row, left to right, Sacco, mission specialist Dr. Ellen S. Baker, payload specialist Eugene H. Trinh, mission specialist Carl J. Meade, payload specialist Lawrence J. DeLucas and Prahl.

In 1989, NASA put out a call for candidates to fill four payload specialist positions for USML-1. Unlike full-time mission specialists, who are career astronauts, payload specialists are scientists chosen to carry out particularly complicated experiments or to take charge of highly specialized payloads on specific shuttle missions.

Two of the payload specialists for USML-1 would actually fly on the shuttle; the others would be backups who would undergo the same training and be prepared to join the mission in the event that one of the primary specialist was unable to fly. One mission and one backup slot each would go to experts in fluid dynamics; the other positions were reserved for specialists in crystal growth.

The announcement rekindled Sacco's childhood space dreams; almost instantly, he was on the phone to a colleague, who agreed to nominate him. Remembering an earlier, unsuccessful application to the astronaut corps, he waited anxiously for word from NASA. This time, he was not disappointed; he had made the semifinals and would compete along with seven other scientists for the four positions.

The culling process included a grueling, week-long physical and psychological examination. "We were then given an enormous amount of material to read—a whole file cabinet full of technical information," Sacco says, "and were quizzed on various aspects of it by members of NASA's Investigators Working Group."

NASA PHOTO

Sacco and fellow crystal growth expert DeLucas train in the spacelab mock-up in Huntsville, Ala.

On Aug. 6, 1990, Sacco received word that he had made the cut. To reach space, though, he still had to convince NASA to pick him over his competitor, Lawrence J. DeLucas, an expert in protein crystalization at the University of Alabama, whose experiments had flown on several previous shuttle missions.

The road to the final decision started later that summer, when Sacco, DeLucas and the two other payload specialists began traveling two weeks each month to the universities, corporations and NASA centers preparing more than 30 experiments to be flown on USML-1.

"Once we were thoroughly familiar with the experiments," Sacco says, "we started working in the Payload Crew Training Complex at the Marshall Space Flight Center in Huntsville, Ala., where they had a complete, working mock-up of the spacelab. The only thing it lacked was microgravity."

Working 12-hour days, the payload specialists and the five-person USML-1 crew (commander Dick Richards, pilot Ken Bowersox, payload commander Bonnie Dunbar, and mission specialists Ellen Baker and Carl Meade) ran through the mission timeline again and again, evaluating and fine-tuning the planned activities. The timeline mapped out the crew's actions over the 13-day mission in excruciating detail. Every activity—from running experiments to eating and sleeping—was broken down into five-minute intervals.

The crew's training also prepared them for daily life in the space shuttle, the world's most sophisticated spacecraft. They learned how to handle materials in an environment where a tiny drop of water floating free can be disastrous. They were taught to survive emergencies, to communicate with people on the ground, and to do the most mundane things—from moving about to going to the bathroom—in the absence of gravity.

To experience the sensation of riding a rocket into orbit, Sacco was spun in a centrifuge at more than three times the acceleration of gravity and wisked through high-speed aerobatics in a T-38 jet high over the Gulf of Mexico. To learn to survive a water landing, he donned a 90-pound

spacesuit and was dropped 30 feet into a swimming pool, where he had to swim out from under a waterlogged parachute and tumble backward into a life raft.

He scrambled through escape drills in a shuttle mock-up and jumped out of airplanes to prepare for a launch disaster. He practiced crawling through the spaceplane's top windows and rappeling down its sides so he could flee a crash-landed shuttle. He learned to use a fire hose to create a curtain of water so he could survive a launchpad fire. And, he studied everything from emergency medicine to using the many shuttle and spacelab computer systems.

To prepare physically, Sacco followed an aerobic exercise and weight-training program custom tailored to his body, submitting to frequent physical exams that charted his progress. And he let a NASA dentist drill out and replace his fillings to eliminate air pockets that could cause painful swelling in the reduced atmospheric pressure inside the shuttle.

Near the end of the first year of training, NASA made its final selection: barring unforeseen circumstances, Sacco would remain on the ground. "As you can well imagine, this was not the news I wanted to hear," he wrote in a memo to the chemical engineering faculty. "I will continue to do my best to help USML-1 be a successful mission for this nation."

While training continued, Sacco did his best to carry out his duties as Chemical Engineering Department head, conducting business during daily phone calls to Worcester. He also supervised the development of the Zeolite Crystal Growth Experiment, the work of a design team consisting of Sacco, Thompson, Dixon, Giacomo P. Ferraro Jr., the department's principal lab machinist, and Nurcan Bac, a visiting professor from Middle East Technical University in Turkey.

The ZCG comprised two primary pieces of hardware: the autoclaves in which the alumina and silica solutions would be mixed and in which the crystals would grow, and a furnace in which to heat the autoclaves. Sacco sketched out the basic design for the furnace, a 70-pound cylinder roughly the size of a small microwave oven. Running the length of the cylinder were 19 aluminum tubes into which 38 autoclaves (19 primary units and 19 backups) would be placed. The tubes were arranged into three zones: a center tube surrounded by a circle of six tubes surrounded, in turn, by a circle of 12.

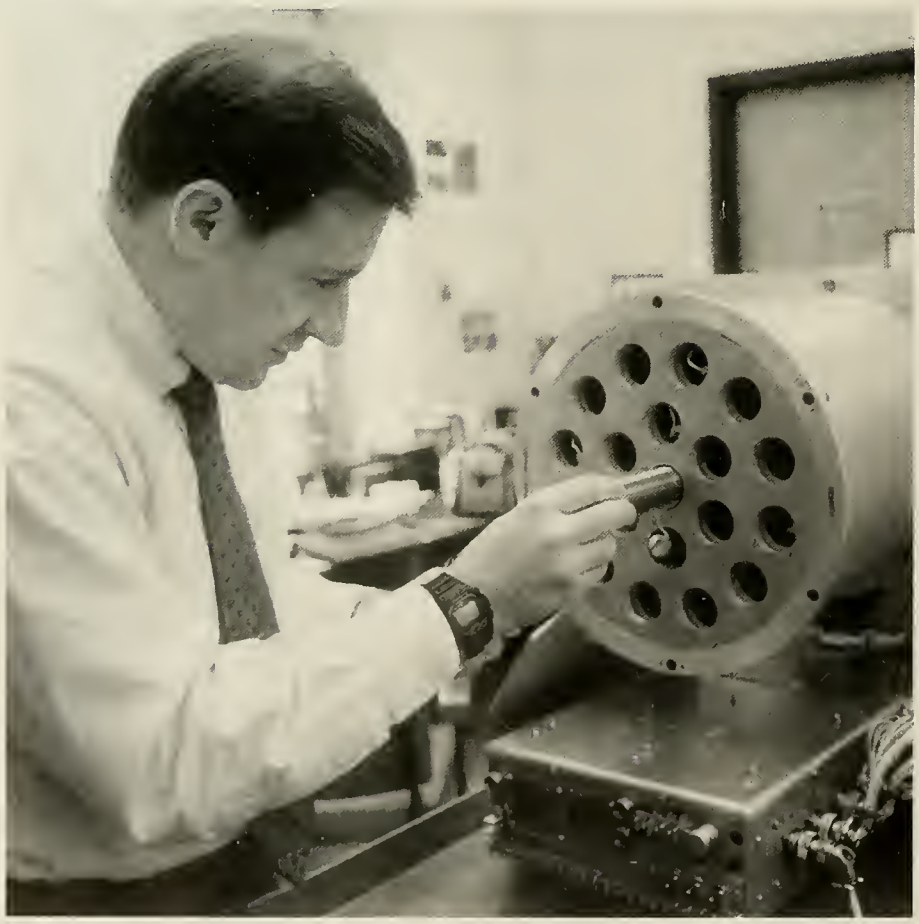
The three zones would provide ideal growth environments for the three zeolites WPI planned to grow during the mission. Since each zeolite grows best at a different temperature, it would be necessary for each zone to be maintained at a distinct temperature setting, ranging from 175° C at the center to 95° C in the outer ring. To confirm that the furnace could accomplish this using the 100 watts of power NASA had allocated the experiment, Dixon developed a computer program to model the device's thermal behavior.

With just a year and a half remaining to develop flight-ready hardware, Sacco, Ferraro, Bac and Douglas White, the department's electronics technician, spent two weeks turning Sacco's sketch into a working prototype. "We called on WPI alumni who gave us bargain basement prices on some of the components we needed," Sacco says. "As a result, we built it for just $40,000."

With actual hardware in hand, the team fine-tuned the design. At the same time, Dixon used the prototype to test the predictions of his computer model. "Since the predictions and the real data didn't always agree," he says, "I used my best judgement to develop the temperature profiles that ultimately appeared in the crew procedures. During the mission, the temperatures we saw agreed very well with those profiles, which made a good impression at NASA."

While work progressed on the furnace, Bac and Ferraro designed the autoclaves. Machined from aluminum, steel and titanium, these tubes contained separate

NASA PHOTO



NEIL NORUM

Below, Sacco inserts an autoclave in the back-up ZCG furnace, which was used in the control experiment at WPI. Above, he undergoes NASA water survival training.

chambers for the alumina and silica solutions. When turned with an electric screwdriver, a teflon paddle inside the autoclaves pressurized one chamber, forcing its contents into the other. Running the screwdriver in reverse pulled the mixture back into the empty chamber. Several complete cycles—called activations—were needed to thoroughly mix the gel.

The task of building prototype autoclaves fell to Ferraro. "His expertise as a precision machinist made it possible," Sacco says. "He was so good, NASA machinists wanted to fly out here to learn how to build these things to such tight tolerances."

After it had received NASA approval (the documentation to satisfy the agency's safety and design requirements would ultimately fill two file cabinets), the furnace design was turned over to Teledyne Brown Engineering in Huntsville, Ala., and Intech Inc. in Santa Clara, Calif., which produced a flight-ready furnace and a duplicate unit to be used in a control experiment at WPI. The autoclaves were built by a precision machine shop in Alabama.

Teledyne Brown also built the electric screwdriver and an attachment to fit the socket in the autoclaves. As the WPI team prepared for a critical NASA readiness review just a few weeks before launch, it became apparent to Ferraro that the attachment was not strong enough and might fail in use. With too little time to design and test a new part, he found a solution at a local hardware store.

"During the review, NASA pointed out the problem," Ferraro says, "and asked how we could solve it. From my pocket I pulled a $3.80 part I had modified and said we should make something like that. The NASA guys looked it over and said, 'why don't we just use this one.' So we replaced an $8,000 device with a $3.80 part from the hardware store."

Perfecting the hardware was just half of the battle. Without a thorough understanding of the chemistry of the zeolites the team had chosen to grow, it would be difficult to later interpret the results of the ZCG. Under the direction of Thompson, a team of graduate students ran countless samples under a wide range of conditions and studied the results.

"One problem with processing in space is that you have to know what you get on the ground," Sacco says. "You have to know everything that affects it, otherwise you won't be able to tell what was due to microgravity and what was caused by something else. That's an evolving problem, because zeolites are so complicated in solution you never know exactly what's going on. But we've probably done more experiments on this than anyone else in the country."

Nurcan Bac, left, and Giacomo Ferraro with the truck they used to transport their supplies to Florida.

Finally, working against the odds, WPI delivered completed hardware to NASA on schedule and within its assigned budget. "It often takes seven to eight years to develop a space experiment," Sacco says. "NASA didn't think we could do it in 18 months. Fortunately, they were flexible. They allowed us to miss a few critical design reviews early on. And a few times when we got stuck, mission manager Charlie Sprinkle had his people help us write documentation. In the end, though, we came through."

For nearly two years, the ZCG team had labored as a group. But as the launch date for USML-1 approached, the team members prepared to split up, for their jobs would now take them far afield.

As an alternate payload specialist, Sacco would spend the mission working 12-hour shifts at a console at the Marshall Space Flight Center in Huntsville, Ala., where he would serve as the primary communications link between the astronauts and the more than 140 scientists on the ground anxiously watching their experiments unfold. It would be the most grueling work he had ever done.

"Being an APS is the toughest job in the world," he says. "You have to be emotionally ready to fly on a mission where your life is at stake. You have to be functionally literate in all the orbiter systems. But you also have to know more about the mission science than the flight crew, because it's your job to talk with the scientists on the ground and translate their needs into language the crew can understand."

Dixon and Thompson would also find themselves at Marshall. Working eight-hour shifts alongside representatives from Teledyne Brown and Intech, they monitored the ZCG's status and stood by to come up with solutions should anything go wrong.

If Sacco, Dixon and Thompson were the actors in the ZCG drama, it fell to Bac and Ferraro to set the stage. In mid-June 1992 they loaded a complete chemistry laboratory and the better part of a machine shop into a rental truck and headed south. On June 18 they arrived at the Kennedy Space Center in Florida, where, along with postdoctoral research associates Eric Coker and Juliusz Warzywoda and graduate student Ipek Guray, they spent 16 hours unloading the truck under the watchful eyes of NASA quality-control engineers.

Over the next few days, they would prepare alumina and silica solutions and load them into more than 80 autoclaves (including 38 for the shuttle experiment and 38 for the duplicate experiment in Worcester). Early on, it became apparent that the tolerances on the internal parts of some of the autoclaves made by the firm in Alabama were off by a few thousandths of an inch—just enough to create friction when the

The flight autoclaves packed in their stowage box.

Working in an assembly line, WPI's Kennedy Space Center team prepare the autoclaves for USML-1. They are, from left, Robert Whitmore from the Battelle Advanced Materials Center, graduate student Ipek Guray, postdoctoral fellow Juliusz Warzywoda, Bac, postdoctoral fellow Eric Coker and Ferraro. The team's work earned praise from NASA.

parts were turned by the electric screwdriver. That friction, they knew, could prevent the solutions from mixing thoroughly. Ferraro set up the tools he'd brought from Worcester and, racing the clock, spent 12 hours remachining the parts.

Ultimately, the autoclaves were loaded, packed into labeled bags, placed in a box, and turned over to NASA on June 23. At the same time, Teledyne Brown representatives handed over the screwdriver and a tool the astronauts would use to remove the autoclaves from the furnace. As that tool changed hands, a strip of Velcro fell off its handle.

Without that strip, the astronauts would be unable to secure the tool to Velcro strips in the shuttle. If it could not be so secured, the tool could not fly, according to NASA safety rules. If the tool didn't fly, the experiment couldn't be run. Suddenly, two years of work was in jeopardy because of a tiny strip of plastic. Without blinking an eye, Ferraro reached into a bag of equipment he'd brought from Worcester and produced the prototype tool—with its Velcro strip securely fastened. Though it was not flight certified, NASA inspectors gave it their blessing. Once again, Ferraro had saved the experiment.

For Bac, Ferraro and the graduate students, it had been an exhausting five days. As they prepared to pack up, mission manager Sprinkle and his assistant, Paul Gilbert, stopped by to compliment the WPI team on a job well done. Similar compliments would soon reach Sacco, Dixon and Thompson in Huntsville. "Two people who were at Kennedy took it upon themselves to tell us what a wonderfully professional and dedicated group we had and how smoothly the operation had gone," Thompson says. "They didn't have to do that."

On the morning of June 25, Bac and Ferraro watched the USML-1 crew board a van for the launchpad, then took their seats in the VIP viewing area to see *Columbia* rise on a massive column of flame and smoke, roll gracefully, and begin its journey into space.

With mixed emotions, Sacco watched the launch on television at his console in Huntsville. "People often ask me whether I felt bad about not being up there," he says. "I did, but not for the reason they think. I had lived with those guys for two years; they had become like family. Suddenly they were going off to do something I knew was dangerous, and I felt I should be with them. I felt almost like a traitor, because I was no longer putting my ass on the line like they were."

Sacco quickly learned that his job would be as challenging—if not more so—than those of the seven men and women orbiting overhead. Pulling on his headset, he felt as though he had landed in a simultaneous translator's nightmare. Into his ears flowed a constant stream of voices—up to 14 conversations at once: scientists, engineers, spacecraft operations people, and dozens of other men and women talking to Sacco and to each other.

He says he quickly became adept at picking out of this cacophony the information he needed. As a scientist and an astronaut who had trained with the spacelab crew, he was in a unique position to work with the rest of the mission scientists to fix the problems the astronauts would encounter and to relay the solutions back up to the crew.

"An astronaut's on-orbit time costs about $23,000 a minute," he says. "When they have a problem, they don't waste time looking up the answer—that's done on the ground. So I had to be able to focus everyone on the problem at hand." In addition to solving problems, Sacco worked with timeline engineers, crew procedure engineers and others to continually revamp the mission schedule—often several days into the future—and to make sure that valuable time on data and television downlink channels would be available to scientists who needed them.

"The researchers were always afraid they were going to lose their science," Sacco says. "Every one of those guys was a world-class scientist, and if they thought you were trying to take away a minute of their time, they'd get big-time upset." In the end, Sacco says, careful rearranging of the timeline allowed the USML-1 crew to actually get more work done on the science experiments than was planned, an extraordinary achievement.

Once, when a potential leak in a seal on a glovebox attached to a large crystal growth furnace placed a portion of the mission science in jeopardy, Sacco devoted one of his 12-hour shifts to working with hardware experts to come up with a solution. His efforts earned him a special recognition award from NASA administrator Daniel S. Goldin. But most of Sacco's time in Huntsville was spent in the pressure-cooker environment of the APS console.

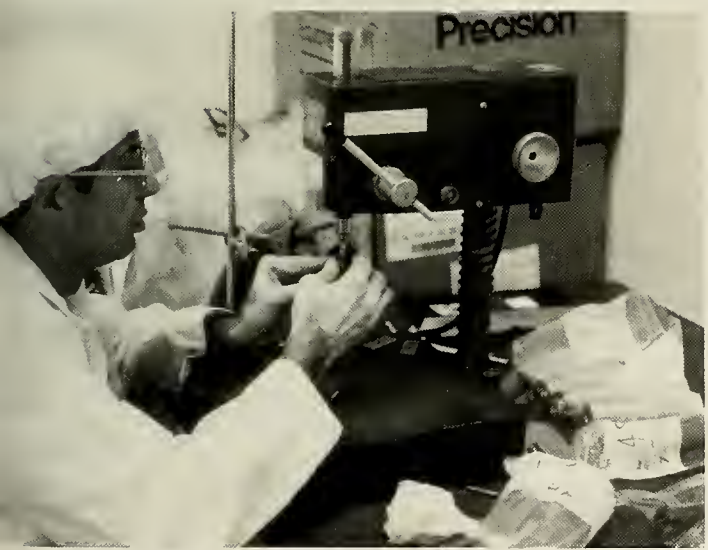
"As an APS, I had to be prepared for emergencies," he says. "If something went seriously wrong with an experiment, it could require a split-second decision. I had a lot of people backing me up, but I was the crunch point; I had to focus it and voice it up to the crew. I was also given the authority to question a command and stop it from going up."

NASA PHOTO

Wearing protective goggles, Bonnie Dunbar prepares a ZCG autoclave in *Columbia*'s mid-deck. When friction due to a machining problem drained the batteries in an electric screwdriver she was using to activate the autoclaves, she finished the job with a ratchet wrench.

At the end of each shift, Sacco spent an hour with the scientists he'd worked with that day to ask how he might better serve them on his next shift. After taking time for dinner, he'd return to his room, utterly exhausted, and try to grab some sleep before returning to the control room an hour early to confer with fellow APS Joseph M. Prahl, professor of engineering at Case Western Reserve University, who worked complimentary 12-hour shifts on the console.

"Al was a real asset to the flight," says payload commander Dunbar. "When we are flying flights like this, which are a combination of science and operations, it's important to have a good mix of the two [in an APS], because he has to make real-time decisions—and make sound ones. He has to interpret a lot of information in a few words. Al was an indispensable contributor to the success of the mission."



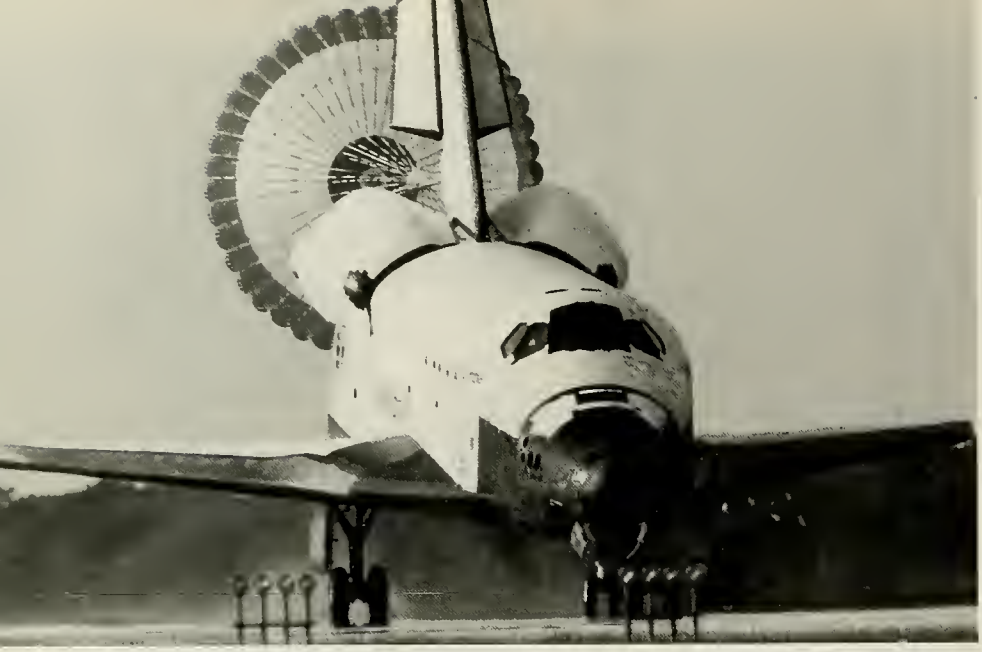
Ferraro works against the clock to remachine the autoclaves.

Early on the first day of the mission, Dunbar started the glove box experiment for the zeolite crystal growth team. As she worked, she noticed something odd about one of the clear-plastic autoclaves and asked Sacco for his opinion. What Sacco saw on the television screen looked like some sort of seepage inside the autoclave. But he didn't say seepage; without thinking, he called the phenomenon a leak.

"Immediately," Dixon says, "I had a bunch of people on my headset saying, "Leak? What leak? Tell me about this leak. Is there any danger? Can anything get out?' So I had to tell them, 'In this case, leak means it's contained.' You learn that the first thing you say is, 'it's contained—it's not coming out.'"

Bac, Ferraro and Coker, who were also watching the experiment on TV, knew exactly what was happening. Because of the machining problem, which Ferraro had not been able to correct completely, capillary action was causing the alumina and silica solutions to "wick" harmlessly to the inside wall of the autoclave. Within minutes, they called Dixon, who relayed the information to Sacco. As quickly as it arose, the furor over the "leak" subsided.

Later that day, Dunbar began activating the ZCG's autoclaves and loading them into the furnace, which, because it would need little attention once fired up, had been placed in the shuttle mid-deck rather than



NASA PHOTO

After a record-setting 14-day mission, *Columbia* touched down at the Kennedy Space Center on July 8, 1992. On board was a precious cargo: a box loaded with 38 autoclaves containing zeolite crystals grown in microgravity.

in the spacelab module. But before she could finish, the electric screwdriver gave out. Due to the machining problem, "there was a little more resistance than we'd anticipated," she says, "which used up the batteries. So we went to a manual activation. We had to be a little creative with our toolkit. We got a ratchet wrench out, made the attachment, and went from there."

After about two hours, the furnace was loaded; Dunbar screwed on the faceplate and turned on the circuitry. In about eight hours, the furnace would reach its operating temperature. For Dixon and Thompson, the excitement was over. "Because the planning had been so successful, there was little for us to do," Thompson says. Dixon puts it this way: "We said all through the practice runs that we'd be bored stupid, and we were."

But one person's boredom is another's delight. Up in *Columbia*, Dunbar could not have been happier about the ZCG's success. "We always go into working a new piece of hardware in zero-G with the assumption that it's a research and development environment, because you can't simulate zero-G for any significant time on the ground," she says. "You give it your best engineering and science judgement, but you provide for the fact that there may be problems. So I was very pleased that they got up there, they held the temperature the way they wanted to, and they controlled it the way they wanted. We never had to intervene. I think they get an A+ for operations."

For Bac and Ferraro, there was little time for boredom. Having loaded the truck, they returned to Worcester to prepare to run the duplicate ZCG along with Coker, Warzywoda and Guray. Using information relayed by Dixon and Thompson, they prepared the autoclaves exactly as Dunbar had done, then monitored the furnace to make sure its temperature profile matched that of the space unit. Later, by comparing the results of the two experiments, the researchers would be able to determine whether microgravity really made a difference in the size of the zeolites they grew in orbit.

Nearly nine days after it was activated, the ZCG was shut down and allowed to cool. Dunbar then retrieved the autoclaves and returned them to their stowage box. In Worcester, Bac boarded a plane and headed for Edwards Air Force Base in California to collect the box. He awoke the morning of *Columbia*'s scheduled landing to find that, due to bad weather at Edwards, the mission was being extended to a record 14th day. He also learned that the landing site had been changed to Florida.

Hopping another plane, he arrived at Kennedy Space Center just in time to retrieve the autoclaves and head for the airport once more. The return of the autoclaves to Worcester brought down the curtain on the Zeolite Crystal Growth Experiment. But ahead of the WPI team lay the task of examining and learning from the crystals they had grown.

For Sacco, the end of the mission brought his first real chance to rest after more than two years of working in high gear and two weeks of 14-hour days. "I didn't feel it right away," he says. "The excitement and adrenaline kept me going. But two days after I got off console, I was sleeping 12 hours straight, and during the 12 hours I was awake I wasn't worth anything."

With the help of Ronald R. Biederman, professor of mechanical engineering, the WPI team put their space-grown crystals under the electron microscope. They also studied them with x-ray diffraction, x-ray photospectroscopy and nuclear magnetic resonance. What they saw was encouraging.

"We got enhanced size, which is what we had predicted," Sacco says. "Compared to the best crystals we've ever grown in our labs here at WPI, which are about 50 to 90 microns (millionths of a meter) on a edge, the space crystals were 40 percent larger in linear dimensions, 96 percent larger in area and 200 percent larger in volume." They also appear to be far more perfect than Earth-grown crystals, he adds.

(It's important to note, Sacco says, that WPI's best Earth-grown crystals, which were produced under carefully controlled conditions, are significantly larger than the crystals typically used in industry. The crystals produced in space are many times larger than those tiny zeolites.)

While the experiment was a success, Sacco says it didn't accomplish everything

The space zeolites proved significantly larger and more perfect than those grown in the control furnace back at WPI.

NASA PHOTO

During the USML-1 mission, Sacco, as an alternate payload specialist, served as the primary communications link between the astronauts and the scientists and engineers on the ground. Working at this console at the Marshall Space Flight Center, he helped solve problems the spacelab crew encountered and continually reworked the mission timeline. Sacco is shown here with, left to right, Anna Bathew, NASA data management coordinator, Alan Johnston, crew interface coordinator, and Karla Kochevar, a timeline engineer.

the ZCG team had hoped. In particular, the mixing problem probably prevented the crystals from growing as large as they might have. "We got a scientific gold star," he says, "but for what we eventually want to accomplish, we have to go much further."

NASA, pleased with the results of the first run of the ZCG, has already booked the experiment on Spacehab 1, a small spacelab set to fly on a five-day shuttle mission in the spring of 1993. Pending the results of that flight, the experiment should also be aboard a second Spacehab mission in 1994 and on USML-2 in 1995. The WPI researchers have even been given space on the proposed space station *Freedom*.

"The idea of this preliminary experiment was to demonstrate that microgravity either does or does not have something to do with the growth of zeolites," Thompson says. "It appears at this time that it does, so the objective was met. What we have to do in the next several months is to interpret the data on some firm scientific basis and see what the next logical step will be."

Sacco says the next run of the ZCG will benefit from better machining of the autoclaves, resulting in better mixing. In addition, the results from the first experiment demonstrated clearly which mixing strategies work best, so only those will be used next time. Because of the short duration of the Spacehab mission, the team will not be looking to grow larger crystals—that will have to wait for longer missions later on.

Ultimately, though, Sacco says the WPI team expects to grow crystals significantly larger than those produced on USML-1—perhaps as big as half a millimeter to a millimeter on a side. Crystals that big, if produced in sufficient quantities, could revolutionize the chemical processing industry, he notes. In particular, large crystals will greatly enhance the purification of chemicals and drugs. Since separations account for 65 percent of the cost of most chemical products, enhancing purification will significantly lower production costs.

Large crystals will also make it easier for chemical engineers to study what makes zeolites tick. With this new knowledge, they can custom design new zeolite catalysts that will increase the yields of many high-volume chemical industries and reduce waste products at the same time. Will such applications justify the significant cost of manufacturing zeolites in space? "If I can spend $1 million to grow crystals that improve the yield of gasoline refining—a multibillion-dollar business—by 1 percent," Sacco says, "then that $1 million will yield billions in savings."

For the moment, though, Sacco and the rest of the ZCG team are thinking about a different sort of payoff—the recognition their work has helped bring to the Institute. "WPI's name is solid gold at NASA now," Sacco says. "We're considered almost a miracle school. People don't know what to make of us. A lot of the university people involved with USML-1 had never heard of us, because we are primarily an undergraduate school.

"I think we really showed them, and it will pay dividends beyond everyone's imagination. We came together in a moment in time and decided that this experiment was bigger than everybody's ego, professional development or leisure time. We decided we were going to do it. And we did it as good as, if not better than, anybody else could have."

Court of Honor

By Ruth Trask

As America's Top Judge, Ernest Hayeck Metes Out Justice With Compassion, Firmness and Humor

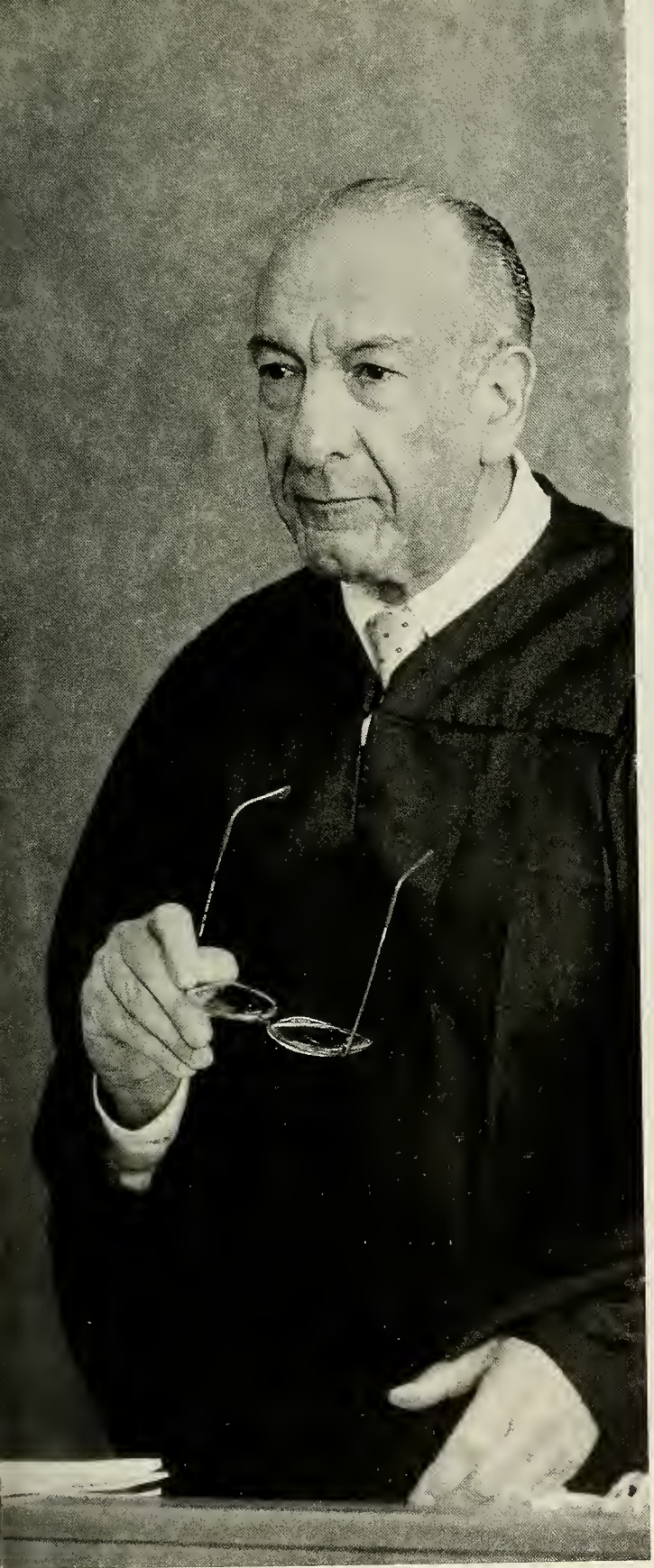
This is beyond my wildest dreams," says Worcester Central District Court Judge Ernest Hayeck '47, who received one of the American Bar Association's highest honors at the organization's annual awards ceremony in July. "Only in America could such a thing come true. I happened to be in the right place at the right time. I was lucky."

As the recipient of the ABA's Franklin N. Flaschner Award, Hayeck was recognized as the top judge in the nation. While Judge Hayeck may modestly attribute this, the latest and most prestigious in a long list of honors he has won, to luck, his colleagues—and even some of the convicts he has imprisoned—tell another story. In a nutshell, they say he bends over backward to be fair to all who come before him—not only defendants, but victims, as well.

In fact, Hayeck's concern for the welfare of victims has brought him to national prominence. When he was chairman of the National Conference of Special Court Judges of the ABA, he helped write a Statement of Recommended Judicial Practices that has been used as a model for victims' rights legislation across the country.

His leadership, along with his role in securing a $250,000 grant from the U.S. Justice Department, resulted in the National Conference of the Judiciary on the Rights of Victims. At that conference, held in 1983, judges from every state in the nation were brought together at The National Judicial College to discuss the problems and rights of victims.

While acknowledging the importance of the rights of defendants, which are carefully defined in American law, Hayeck says victims of crime often receive serious physical,



PHOTOS BY JANET WOODCOCK

Judge Ernest Hayeck's dedication to the rights of victims has earned him the respect of his peers.

psychological and financial injuries as a result of crimes committed against them. Before the National Conference of the Judiciary promulgated its recommendations, victims' rights had never been clearly defined, he notes.

"Victims of and witnesses to crime frequently must take time off from work and make other personal sacrifices, possibly subjecting themselves to risk of intimidation and injury," he says. "The criminal justice system depends on the willing cooperation of victims and witnesses in order to perform its primary function of protecting all citizens in this country."

To give victims and witnesses fairer treatment in criminal cases, Hayeck proposed that they be provided essential information about court procedures and courthouse facilities; be allowed to participate, and where appropriate, give input through the prosecutor to testify in all stages of judicial proceedings; and be protected from harassment, threats, intimidation and harm. He also recommended that judges at the trial and appellate levels be encouraged to participate in training programs dealing with the rights, problems, needs and legal interests of crime victims.

Victims of crime, he says, should not be victims of the criminal justice system, as well. By virtue of their position of authority in the American judicial system and their prominence in their communities, judges can play a critical role in making sure that doesn't happen. He says judges can take an important step toward improving the lot of victims by simply evaluating their own attitudes and the attitudes of their staffs toward these individuals.

With the national spotlight focused on the rights of victims, a number of victims' rights groups, including the National Victim Center, have been organized over the past decade. "Incidentally," Hayeck says, "I met Christine Edmunds, director of program development for the National Victim Center, at The National Judicial College in August. I was pleased to learn she is the niece of Professor Emeritus Albert Schwieger, one of my favorite former WPI professors."

Hayeck is noted for running a simple, straightforward court, where justice is meted out with compassion, firmness and humor. "I want the prisoners to know why they must go to jail," he says. "I want them to feel the seriousness of what they have done. I don't believe in simply slapping wrists."

For example, when a gang of youths desecrated a cemetery, Hayeck sent them to jail rather than giving them the option of community service, as other judges have done in similar cases. "Most of those tombstones belonged to poor, elderly families who couldn't easily replace them," he says. "They were heartbroken and devastated by what those boys did. The culprits deserved to go to jail."

Over the years, a surprising number of prisoners have thanked Hayeck for his brand of justice, saying it helped deter them from returning to familiar patterns when they were released from jail. But Hayeck is no "hanging judge." His kindnesses on the bench are legendary.

Once, when one of the parties in a lawsuit would accept nothing less than $350 and the other party would pay only $300 and not a penny more, Hayeck opened his wallet and made up the $50 difference on the spot. "Fifty bucks made

In his Worcester courtroom, Hayeck is known for his compassion and fairness, and for his uncanny ability to put people at ease.

all the difference in the world to the kid in question," he said in a newspaper interview at the time. "It seemed like the right thing to do."

Hayeck says he cares about the people in his courtroom as individuals. To put the men and women who come before him at ease, he sometimes gives a brief discourse on the etymology of their surnames, drawing on his working knowledge of several languages. "For the average person, an appearance in court is a traumatic, frightening experience," he says. "I feel that to the extent he can do so, a judge should put people at ease, but without demeaning the dignity or the solemnity of the proceedings."

During his 22 years on the bench, Hayeck has heard a wide variety of cases—civil and criminal—ranging from the simplest to the most complicated and serious. He can lay claim to having presided over the largest medical malpractice jury verdict ever handed down in Massachusetts. In November 1986 a jury awarded a plaintiff $9.72 million in Harlow v. Chin and Massachusetts General Hospital.

As he hears the cases that come before him, Hayeck says he is ever mindful of his role as a public servant. "The court belongs to the people," he explains. "A judge or a judge and jury hear the evidence, determine the verdict, and the sentence is decided by the judge. I never forget for one moment that mine is an awesome responsibility. What I do can have a great and sometimes irreversible impact. But I don't have any problem making up my mind. None whatsoever. If I did, I think I'd belong in another business."

America's foremost judge says he is perfectly happy with his courthouse digs, although they are not luxurious by any means. In fact, he is unabashedly proud of having made it in Worcester rather than in New York City or Los Angeles. He says the gilt trappings of big-city success mean little to him. "I'm a living example of how you can succeed in your own backyard," he says. "The grass isn't always greener somewhere else."

No matter what his location, Hayeck is sought out by those in high places from coast to coast. His colleagues hail him as a national leader in judicial education. Milford (Mass.) District Court Judge Francis J. Larkin, who nominated Hayeck for the Flaschner Award, says "he has compiled an enviable reputation as a judicial-educator who combines broad erudition with powers of clear exposition and eloquent, pungent writing."

Hayeck is a faculty member at the only college for judges in America. The National Judicial College in Reno, Nev., where all of the students and most of the faculty are judges, was established many years ago at the University of Nevada under the aegis of the U.S. Supreme Court. Private funds were sought for the creation of the college, which is affiliated with the ABA. Since the Fleischman Foundation of Reno provided the most substantial initial funding and continuing support, the college was located in the foundation's hometown.

Judges from all over the country and all over the world attend the college. Many states require their judges to attend. In the near future, 100 judges from Russia will enroll. Tuition is substantial and the training rigorous. Classes start promptly at 8 a.m. and run until 5 p.m., seven days a week. The faculty serves *pro bono publico*—on a voluntary basis.

It is an honor to be chosen to teach at the college, Hayeck says. Faculty members are anonymously evaluated by all the students for every lecture they give, in every course they teach. If his evaluations drop, an instructor is not invited to return. Hayeck started teaching at the college in 1974 and he has been invited back every year since. His evaluations have been remarkable. For the most recent session, during which he taught advanced evidence, among other subjects, his mean rating was 6.8 out of a possible 7.

In postcourse reviews his students have said, "Judge Hayeck's lectures are clear, concise and practical," and "he is a brilliant man who has a flair for teaching." One student noted, "He should be teaching law school students. They'd love him."

In addition to serving on the faculty at The National Judicial College, Hayeck served the maximum allowable six years on the college's board of directors and was vice chairman of the board when U.S. Supreme Court Justice Warren Burger was chairman.

Also, long concerned with the rights of prisoners and minorities, Hayeck helped spearhead the first National Conference of the Judiciary on Jail and Prison Crowding. He is a longtime member of the ABA Commission on Opportunities for Minorities in the Profession. While he was chairman of the Judicial Administration Division (JAD) of the ABA, he created the Judicial Administration Division Task Force on Minorities in the Judiciary.

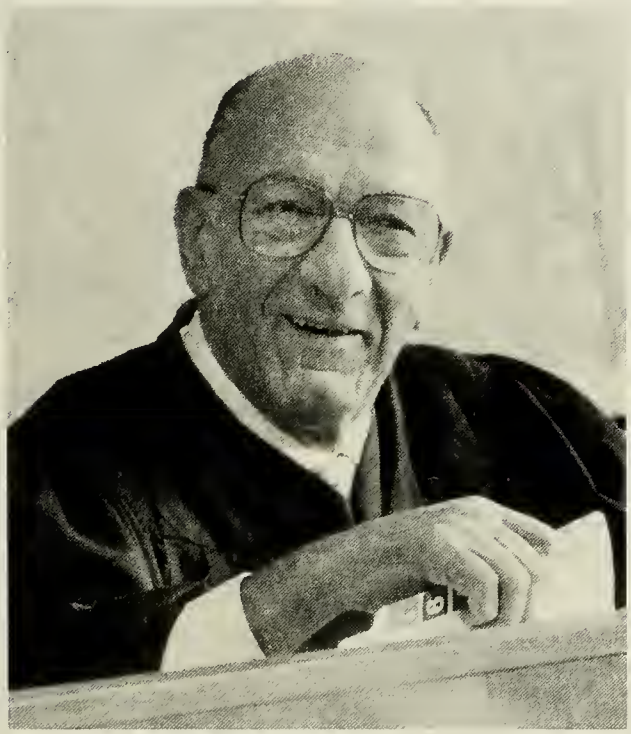
Francis S. Moran Jr., executive director of the Boston Bar Association, says, "Few if any lawyers in the country have done as much to further the cause of broadening opportunities for minorities in the legal profession as Judge Hayeck. In his years on the bench, he has

also made a profound impact on the improvement of judicial education, not only in Massachusetts but in the nation as a whole."

Moran, chairman of the ABA awards board, had good documentation to back up Hayeck's nomination, as Hayeck has served as chairman of the Massachusetts District Court Committee on Judicial Education.

Former Michigan Supreme Court Justice Dennis Archer was the keynote speaker at Hayeck's ABA award presentation in San Francisco in July. Anthony Lewis, a columnist for *The New York Times* and two-time winner of the Pulitzer Prize, also attended the ceremony. As the keynote speaker at the opening assembly of the ABA, Lewis commended Hayeck and quoted him in his speech.

In recommending Hayeck for the award, Justice Archer cited Hayeck's hard work in the ABA Minority Counsel Demonstration Program. He noted that he was also impressed that Hayeck was instrumental in getting the JAD to form a task force that has increased the number of minority judges who belong to the ABA and the JAD, and encouraged more judges to hire minority law clerks. Of Hayeck, he wrote, "A person who thinks of others first, who uses his intellectual skills to demonstrate fairness and to benefit mankind while wearing his heart on his sleeve and providing service to our profession is more than worthy of consideration."



As a teenager, Hayeck never saw himself in the legal profession. He grew up on Grafton Hill in Worcester, where he used to get in trouble for taking mechanical things apart and putting them back together, making his own batteries of copper, zinc and sulfuric acid, and devising his own transformers.

"Justice at home was always swift," he recalls. "Sometimes it was a whack. I had two brothers, and we were always getting into scrapes. Ironically, my parents' favorite caution was, 'Judge not, lest ye be judged.'

"As I grew older, I knew I wanted to study at WPI and teach," he says. After graduating with his B.S. in chemistry from the Institute, he taught at Boston University, where he received his M.A. in chemistry. He then taught at Stonehill College in North Easton, Mass., where he established the chemistry department.

"In 1952, after my younger brother, Albert, a lawyer, was killed in a private plane crash, I decided at his funeral to change careers and go into law," he says. "That was the trigger mechanism that caused me to go to law school."

After receiving his law degree from BU, Hayeck was in private practice in Worcester from 1955 to 1970. In 1970, Francis Sargent, then the governor of Massachusetts, named him a judge. Over the years, in addition to judging and teaching, Hayeck has done a great deal of writing on the law of evidence, on trusts and various other subjects. His accomplishments have earned him several honorary graduate degrees and other professional honors.

Hayeck says what he has found most rewarding about his career is the opportunity to serve society. "Service itself is its own reward," he notes. "The beauty of the U.S. judicial system is that it is the backbone of our free society. We have no armies to back up court decisions. People, in general, respect our court decisions and abide by them, which is not always the case in other countries."

Currently, he says, the courts are on the verge of being overwhelmed. But it's still important to give people the attention they deserve. "Too many judges don't exercise as much latitude in resolving cases as they might," he said in a recent interview with the *Massachusetts Lawyer's Weekly*. He says he's found it effective to help litigants resolve their disputes without the need for a full adversarial trial.

A judge, he says, must never become an advocate for either side, but he or she can make a meaningful contribution to the resolution of a case by being involved in an impartial way. "I think a judge, if he has a knack for it, can move a tremendous amount of work," he said in the *Lawyer's Weekly* interview. "It's much easier to sit there with your mouth shut and try to look learned. But I don't think we can afford that attitude."

Although cognizant of the many problems facing America today, both inside and outside the courtroom ("It's scary everywhere" he says), Hayeck admits to being a red, white and blue patriot, believing in the basic strengths and ideals of our democratic society.

He says he is aghast at the changes that have taken place since he first started practice in the 1950s. Back then he was rarely, if ever, concerned with drug or drug-related cases. Today, he says, his calendar is overflowing with them.

Hayeck attributes his own balanced view of the world to his broad-based education and to his wide-ranging interests. (They include scuba diving, which he has done all over the world, fishing for marlin in Hawaii and the Caribbean, and catching salmon in the Pacific Northwest and Alaska.)

He says he strongly advocates that prospective lawyers broaden their own horizons by taking science and humanities courses along with their studies in law. "I have many engineer friends who never read anything but professional literature," he says. "They wouldn't dream of reading a poem or a novel." An avid reader, Hayeck says he finds this sad.

To those considering law careers, Hayeck has another piece of advice: "Be fair minded." As for himself, he says, "I think I've been totally and irreversibly ruined for the art of advocacy, because as a judge, I see at least two sides to every question."

Bob Sinicrope Shows Students There's Joy and Fulfillment in "All That Jazz"

The original pied piper in the classic children's story led youngsters out of town playing pan pipes. Bob Sinicrope '71, on the other hand, leads his kids out of the country playing the trombone and the string bass. On his résumé, Sinicrope is listed as a mathematics teacher at Milton Academy, a well-known preparatory school in Milton, Mass. While he says he enjoys teaching math, it is his love of jazz, which he also teaches, that has taken him and his young charges around the world.

Thanks to Sinicrope, jazz is big-time at Milton. The school offers full-credit courses in the subject and gives students the opportunity to learn about musical self-expression by playing in the Milton Jazz Combo, which Sinicrope directs. No run-of-the-mill kids' group, the combo has performed from coast to coast, opened for the likes of James Taylor, and received numerous music awards.

"We just won our most important honor ever," reports a beaming Sinicrope. "*Down Beat* magazine named the Milton Jazz Combo the winner in the North American high school small group category in its 15th Annual Student Music Award Competition."

As pleased as Sinicrope and his combo are with this prestigious prize, the highlight of the group's career to date was a February 1992 tour of South Africa, where they performed at the invitation of Abdullah Ibrahim, one of the world's most outstanding jazz composers and pianists.

That remarkable opportunity followed Ibrahim's performance at Milton Academy last year at a benefit for the school's South African Scholarship Fund. Ibrahim was so impressed with Sinicrope's combo that he invited the students to appear at concerts in his native land. "I want the spirit of the Milton Jazz Combo shared with my South African homeland," he said, following his standing-room-only concert at the school.

To earn enough for the trip, Sinicrope and his group undertook a dizzying concert schedule—performing anywhere they were asked. Within one two-week period they performed three times in Boston: at the Museum of Science, in Copley Place (an upscale shopping mall in the downtown area), and at Aquinas Junior College. "We had to raise money the best way we could," Sinicrope says.

In addition to their own efforts, the combo received generous support from families and friends of Milton Academy. Ultimately, their financial goals were met and, in early February, Sinicrope and the combo, accompanied by Sinicrope's daughter, Alicia, and two other academy representatives, arrived in South Africa.

Highlights of the trip included a concert for the mayor of Johannesburg in City Hall, a performance at a local boys' school, a special performance for Dave Brubeck's son Darius,

J.D. SLOAN

Bob Sinicrope '71 leads the Milton Academy Jazz Combo, named best in its category in a *Down Beat* magazine student music competition.

J.D. SLOAN

Sinicrope chats with South African jazz great Abdullah Ibrahim, who invited the Milton group to perform in his country.

a jazz musician who lives in Durban, and four days spent studying and performing at three township schools. There was also plenty of time for getting a taste of local culture and sightseeing, with the African game preserves being an especially popular attraction.

"We all agreed that the trip was a great honor and a privilege," says Sinicrope. "We were truly touched by Ibrahim's talent and spirit. The trip was fantasy come to life."

A story in the Milton Academy newspaper noted that Sinicrope, who had invited Ibrahim to the scholarship benefit, was the prime force in turning the dream into reality. "It is impossible," noted the young reporter, "not to see that Mr. Sinicrope has worked beyond belief....the trip would not have been possible without him."

So successful were Sinicrope's international efforts in South Africa, he was selected to spend more than six weeks teaching math and English last summer at Milton Academy's sister school in Beijing, China. It goes without saying that somewhere along the line he introduced the best of jazz to his Chinese students.

Sinicrope has been teaching courses in math and jazz improvisation at Milton Academy for 19 years; in fact, he founded the school's highly acclaimed jazz program. He has been a staff member at Jamey Aebersold's summer jazz camps in Chicago and Louisville for 12 years (Aebersold is the world's best-known jazz educator) and he has directed jazz combos at the John Payne Music Center in Brookline, Mass., for 13 years.

In addition, he has conducted jazz clinics in Australia, China, Jamaica, South Africa and Thailand, as well as in California, Florida and the greater Boston area. Sinicrope, who formerly played the trombone in the WPI Brass Choir, now plays string bass exclusively in his professional gigs. He has played with jazz greats Billy Eckstine, Ernestine Anderson, Bob Wilber, Tiny Grimes, Vic Dickenson, Jo Jones and Warren Vache. In 1987 he was featured at the Worcester Jazz Festival with guitarist Gary Sargent. More recently, he accompanied Shirley Bassey at Symphony Hall in Boston.

Sinicrope used to perform with his good friend, Richard Falco, who is director of jazz studies at the Institute. Today he is the bassist in Dick Johnson's Swing Shift, one of the outstanding jazz groups in the Northeast. He also plays regularly with the John Payne Sax Choir, which back on Sept. 25 performed with guest soloist and then-presidential candidate Bill Clinton.

He says playing off campus helps him immeasurably in the classroom and on the podium. "Teaching and performing are art

JANET COLEMAN

When he is not teaching, Sinicrope performs professionally on the string bass and conducts jazz clinics around the world.

forms," he says. "The more you do of one, the sharper your skills become in the other.

"I've been a professional musician for 30 years. In fact, playing music helped pay my way through WPI," Sinicrope says, explaining another important benefit of performing. But more important to him, he says, is the self-expression he finds in performing and the fulfillment he finds in helping others discover jazz.

"I feel fortunate to have had the opportunity I've had to reach others through my teaching and playing. I've had many remarkable experiences in what I do and I am continually learning and growing."

—Ruth Trask

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WPI Journal

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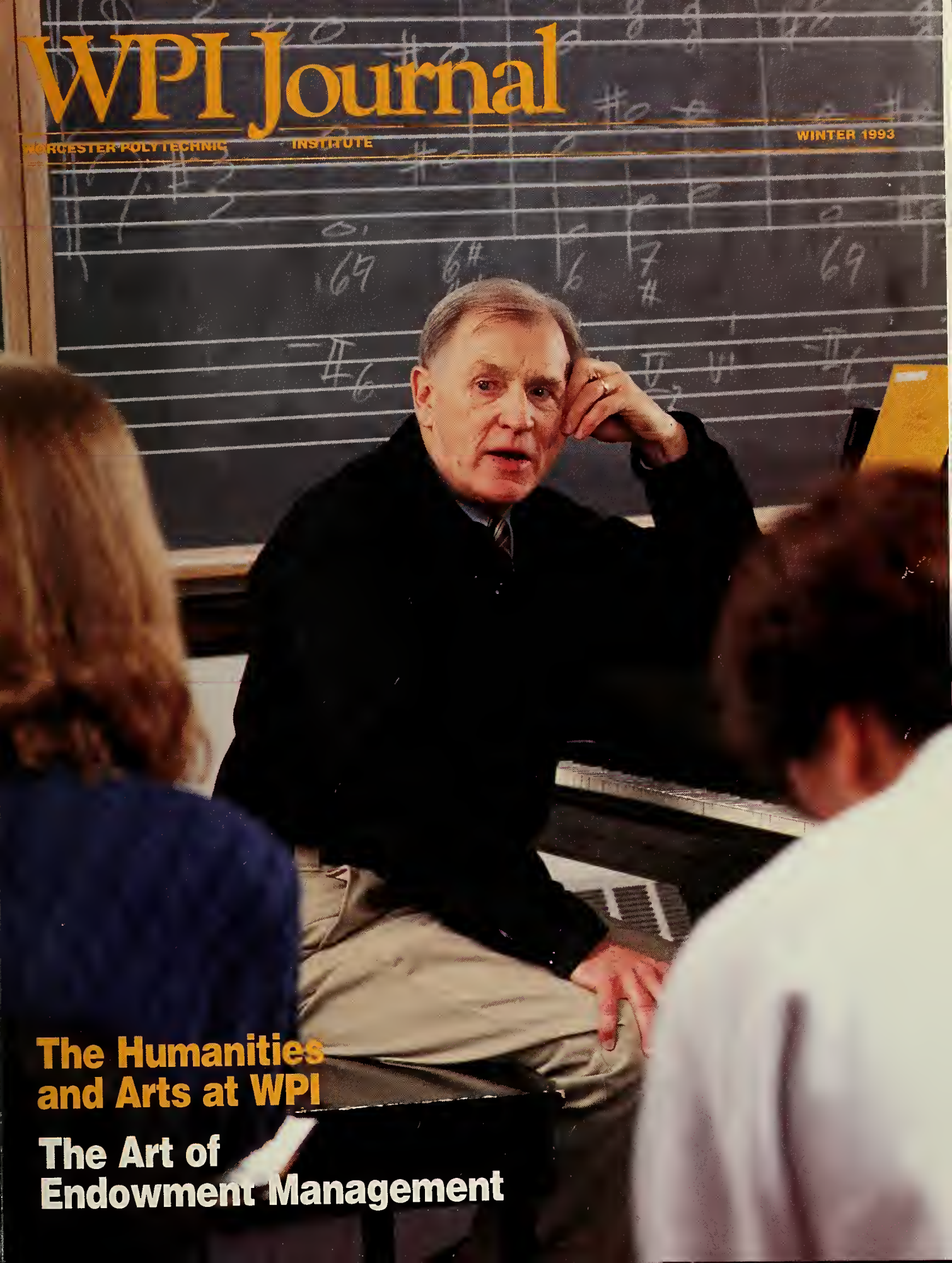
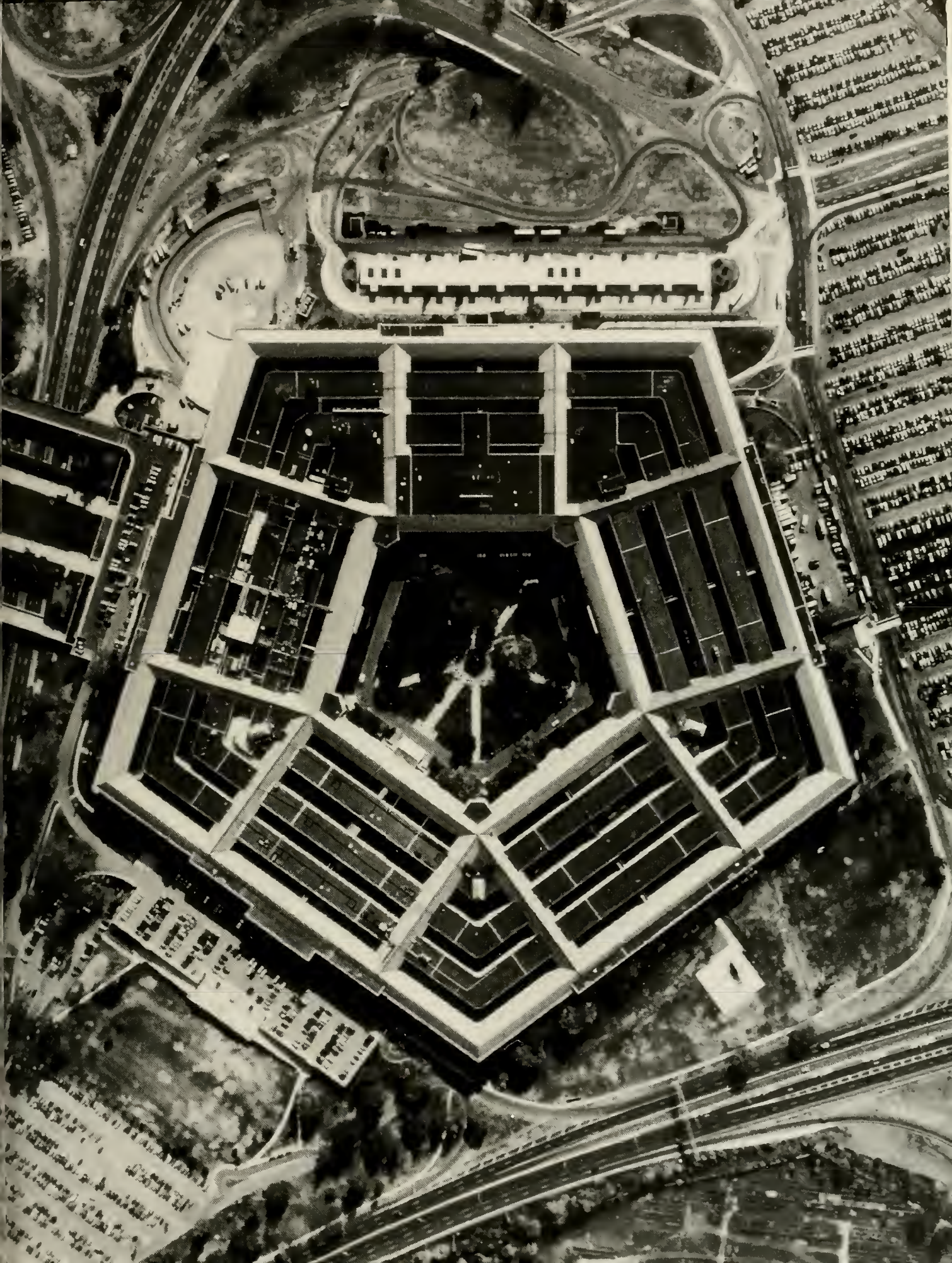
WINTER 1993



The Humanities and Arts at WPI

The Art of Endowment Management



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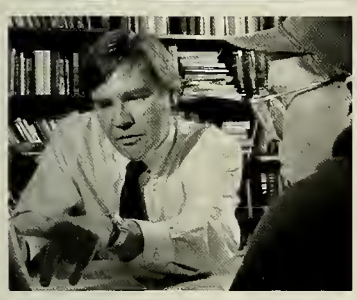

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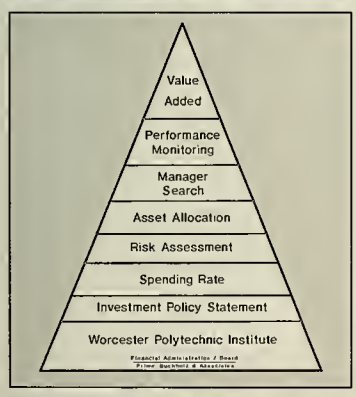

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Front Cover: Music professor David P. McKay, who will retire this year after a 37-year career at WPI, lectures students in the new music classroom in the fully restored Alden Memorial. Story on page 14. Photo by Janet Woodcock. **Opposite:** The Pentagon is also benefiting from a complete renovation, under the direction of Anthony F. Leketa '69. Story on page 22. Photo courtesy of the U.S. Army Corps of Engineers. **Back Cover:** In the shadow of the Washburn Shops, students trudge through the aftermath of a record-setting snowfall last December. Photo by Janet Woodcock.

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Celebrating Alden... The Man and The Building

George I. Alden was just 25 when he joined WPI's original faculty in 1868. He would go on to become one of the college's most renowned educators, a man whose vision not only inspired a generation of students, but helped change the face of engineering education.

Had his achievements ended there, his story would have been remarkable. But Alden, a talented entrepreneur, also helped found Norton Co., one of Worcester's most important corporations. His success in industry made him a wealthy man, and he shared his good fortune liberally with the college where his career began. His generosity continues today through the George I. Alden Trust. Over the years, his gifts to WPI and those of his trust have totaled $8.6 million, making him the Institute's most generous benefactor.

Alden was born in 1843 in Templeton, Mass., where WPI's founder, John Boynton, made his fortune in tinware manufacturing. His mother, Priscilla Alden, was the daughter of Silas and Mary Alden of Templeton; Silas was a direct descendent of John Alden and Priscilla Mullins, passengers on the *Mayflower*, making George Alden an eighth-generation descendent of a *Mayflower* family.

Like many youngsters of the time, he was forced to work several years to raise the funds to enter college. He graduated summa cum laude from Harvard University's Lawrence Scientific School in 1868 and joined WPI shortly thereafter. In addition to his mechanical engineering professorship, Alden was named WPI's dean of the college in 1894 and twice served the Institute as acting president.

In his *Seventy Years of the Worcester Polytechnic Institute*, Herbert Taylor described George Alden as "...a painstaking and thorough teacher, though sometimes given to sarcasm, who gave his students a grounding in theoretical and applied mechanics such as few of his generation could impart."

Alter 28 years at WPI, Alden, along with Milton Prince Higgins, the original superintendent of the Washburn Shops, resigned from the faculty as a result of a dispute with the Institute's third president, Thomas C. Mendenhall, over the shops' operation. In time the action would prove a blessing in disguise for WPI, as Alden put more of his energies into the development of Norton Co., ultimately becoming its chairman and a wealthy man.

He became a WPI trustee in March 1912 and served in that capacity until his death in 1926. The Institute honored Alden, who was for a time vice president of the American Society of Mechanical Engineers, by naming its hydraulics laboratory in Holden (to which he had been a significant contributor—both intellectually and materially) for him, and by awarding him an honorary doctorate in 1926.

When Alden began his WPI career in 1868, engineering was still very much an art. The few schools that offered instruction in engineering were groping for an educational model that in some manner blended instruction with practice. WPI's model, combining classroom time with instruction in a working shops, helped create what became known as the "shop culture," which would serve as a curricular model for several institutions—including Georgia Institute of Technology—from about 1870 to 1900.

As the field of mechanical engineering evolved, the "shop" model gave way to the "school" model, in which the element of practice was relocated from the shop to the laboratory. It was this philosophical

Editor's Note: On April 22, WPI will note the 150th anniversary of the birth of George I. Alden, the Institute's first professor of mechanical engineering. On that day, it will rededicate Alden Memorial, the building given to WPI in 1940 by the George I. Alden Trust.

Alden Memorial recently underwent a major, $2.8 million renovation; beginning on page 14 you'll find a photo essay on its rebirth as a performing arts center. Starting on page 4, you'll also find extensive coverage of the Institute's innovative educational programs in the humanities and the arts.

But before we get to the present and future of Alden Memorial, here's a look at how one of WPI's most beautiful buildings came to be, and, more important, a look at the extraordinary man it honors. This article was adapted from material on George Alden's life written by Donald F. Berth '57, vice president for university relations, and from an essay on the history of Alden Memorial written by Anne B. Littlefield, director of major gifts and planned giving.

change that produced the rift between Alden and Mendenhall.

Fourteen years before his death, Alden established the George I. Alden Trust. He specified that the trust's funds be used to promote education, particularly technical and professional education. Alden's daughter, Clara, who was educated at Wellesley College and held a doctorate from the University of Colorado, became an Alden trustee upon her father's death and helped administer the fund until her own death in 1945.

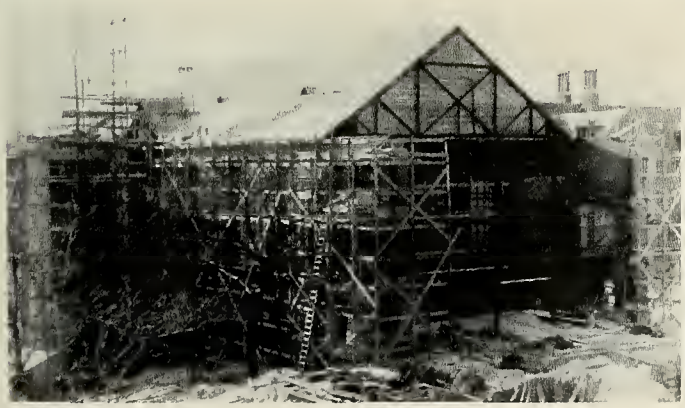
WPI has been the greatest beneficiary of the Alden Trust's generosity. The trust funded a new building at Alden Research Laboratories, created the George I. Alden Chair in Engineering and, most recently, supported the construction of the George F. Fuller Laboratories, among many other projects.

But perhaps its greatest gift to WPI was Alden Memorial. The idea for the building originated with WPI President Ralph Earle, who included an auditorium in his ambitious $1 million campus expansion plan. The trustees approved the idea in 1929 and J. Cornell Appleton of the prominent Boston architects Appleton & Stearns, designers of Sanford Riley Hall (and, later, Higgins Laboratories), was chosen to design the building. The Depression put the plans on hold, but they were revived in 1937 when Earle asked Appleton to update the plans.

Appleton endowed the building with touches of beauty and elegance. This is especially true in the great hall, with its oak paneling, iron chandeliers and eight massive ceiling beams. At either end of the beams are stone figures, each a woman with a shield representing religion, science, music, architecture, knowledge, the arts, sculpture or drama. They were carved by Thomas Miln of Berlin, Mass., whose work can also be seen on the U.S. Treasury and National Archives buildings in Washington, D.C. The windows in the great hall and two in the tower are fitted with stained-glass medallions. The creation of Wilbur H. Burnham, who also worked on the National Cathedral in Washington, the medallions tell the story of American history.

In addition to the great hall, the building was to house a central library with room for 50 percent more books than the original facility in Boynton Hall. There was also to be a room that the Institute's new president, Wat Tyler Cluverius, said would be used "for cocktail parties, tea parties, and other social gatherings." Cluverius initially intended that the room be named for Clara Alden, but when she declined, it was named instead for President Earle's widow, Janet.

Alden Memorial, seen under construction in 1939 in the photo below, provided WPI and the Alden Trust an opportunity to honor the memory of George I. Alden, opposite. Until 1967, Alden housed the Institute's central campus library, left.



The search for funding for the building ended successfully with the George I. Alden Trust. The trustees of the fund had already developed the idea of erecting a memorial to Alden, and the new hall at WPI seemed to fit the bill. In late 1938, the trust informed WPI it would fund the entire project, and the college responded by naming the building for Alden.

Earle died shortly thereafter, but work on Alden Memorial continued. R.L. Whipple Co. in Worcester won the bid to construct the building, and on June 26, 1939, excavation began for the foundation. (The Class of 1942, which recently provided funds for a new plaza adjacent to Alden, beat the contractor to it by four days with its own informal groundbreaking ceremony.)

A 75-man crew worked 150 days straight with no time lost due to inclement weather, finishing the roof before winter descended. Work continued through the coldest months and the building was ready in time for the 1940 Commencement, thus beginning its history as the heart of campus activity.

From 1940 until the late 1960s, the great hall hosted virtually all important college events, including honor society pledgings, academic awards ceremonies, concerts, dances, lectures and plays. A general assembly of the entire college community was held there weekly, providing a forum for the discussion of important issues of the day. The Vietnam War was hotly debated there in the 1960s.

With the start of the WPI Plan in the early 1970s and the concurrent growth of the campus population, assemblies became a thing of the past. The completion of Gordon Library in 1967 and Harrington Auditorium in 1968 freed up room in Alden for new uses, and the building became a home for the Institute's active music and drama programs. With its recent renovation, Alden Memorial is even better suited for this role, one destined to keep it at the center of campus life.

Enriching Life... And Making a Living

BY BONNIE GELBWASSER
AND MICHAEL DORSEY

THE FRAMERS OF THE WPI PLAN KNEW THAT THE HUMANITIES MUST BE GIVEN FAR MORE THAN A TOKEN ROLE IN THE EDUCATION OF SCIENTISTS AND ENGINEERS. WHAT THEY CAME UP WITH MORE THAN TWO DECADES AGO TRANSFORMED HUMANITIES EDUCATION AT WPI AND SET AN EXAMPLE FOR OTHER ENGINEERING EDUCATORS TO EMULATE.

More than 125 years ago, when John Boynton laid down the Institute's philosophical foundation, he wrote, "The aim of this school shall ever be the instruction of youth in those branches of education not usually taught in public schools, which are essential, and best adapted to train the young for practical life."

Like Boynton, Ichabod Washburn, whose gift of the Washburn Shops helped frame WPI's "Two Towers" approach to education, insisted that the new school not be confined to the "theories of science, but as far as possible to the practical application of its principles which will give the greatest possible advantages in the affairs of life." Such a balanced curriculum, Washburn noted, would "add to their personal independence and happiness, while it renders them better and more useful citizens."

But in 1868, as the college began life as the Worcester County Free Institute of Industrial Science, it was clear that the balance of the theoretical and the practical that Boynton and Washburn embraced would not, to any appreciable degree, include the humanities and the arts. In fact, for most of the Institute's early years, instruction in the humanities was limited to a smattering of classroom hours taught by part-time instructors.

The picture brightened in 1872 when the Department of English and Modern Languages was created, funded by a gift from board president Stephen Salisbury II. The new department offered students instruction in English composition and French. Some 32 years later, the Class of 1879 Prize, which now honors outstanding projects in the humanities, was established to recognize the best essays written in composition class each year.

For the most part, that is how humanities instruction at WPI would remain for decades. An optional course in the history of civilization and science was launched in 1934, literature courses were added to the standard offerings in English composition in the 1940s and, in 1959, following a two-year study of the Institute's academic programs, an effort was made to broaden still further the humanities curriculum.

Then came the 1960s. On campuses across the nation it would be a decade of change and growing social awareness, as colleges searched for ways to better prepare students to understand their role in—and responsibilities to—society. At WPI, that search brought on a period of curricular experimentation. One notable experiment was an interdisciplinary program, begun in 1964, that allowed students to earn a bachelor of science degree in either humanities and technology or humanities and science. But for the humanities, the real shake-up was yet to come.

The 1960s culminated in the WPI Plan, an initiative that would catapult the Institute to the forefront of engineering education reform. In drafting the Plan, the faculty and administration carefully evaluated what worked and what didn't in a WPI education as it then existed. They set as their fundamental purpose "to impart to students an understanding of a sector of science and technology and a mature understanding of themselves and the needs of the people around them." They envisioned "a WPI education that should develop in students a strong degree of self-confidence, an awareness of the community beyond themselves, and an intellectual restlessness that spurs them to continued learning."

One of the major issues facing the Plan's framers was how great a role the humanities should play in a technical education. "We decided that a strong humanities component, coupled with the superb technological education our students receive, would make our graduates among the best prepared of any university to succeed in whatever careers they chose," says William R. Grogan, dean emeritus of undergraduate studies and a member of the committee that created the Plan.

To meet that objective, the committee crafted the Humanities Sufficiency program, a radical new way of introducing students of engineering and science to scholarship in nontechnical disciplines (see page 9). The Sufficiency became one of the four pillars of

the Plan (since then, one of those four original degree requirements—the Competency Exam—has been replaced by distribution requirements).

But the Plan was merely a blueprint. To bring it to life, some quite fundamental changes had to take place in the organization of the Institute and in the way it carried out its mission. Few academic disciplines at WPI have experienced that wave of change so completely—or have been so completely transformed by it—as the humanities.

A major step along the road of change was taken in the mid-1970s with the creation of the Humanities Department. Until then, courses in art, English, French, German, history, music and philosophy were taught by the Department of English and History and the Department of Foreign Languages. The Humanities Department united these disciplines under one umbrella and also provided a new home for the decade-old humanities major program.

Since its inception, the department has received a number of program development grants from both public and private agencies. In particular, grants from the National Endowment for the Humanities, the Rockefeller Foundation and the Andrew W. Mellon Foundation have proved instrumental in developing and maintaining a broad and diverse humanities curriculum and in establishing programs and standards for student work in interdisciplinary areas.

Individual disciplines within the department have also benefited from outside support. For example, in 1991 the Fred Harris Daniels Foundation earmarked a two-year, $50,000 grant to enrich the department's art history and architecture, foreign language, and music programs. The grant has already been used to establish an electronic music laboratory in Alden Memorial (see story, page 14) and to enlarge the department's slide collection in art history and architecture. The remainder of the grant is being used to create a modern language laboratory, to be housed in Gordon Library.

Under the direction of history professor JoAnn Manfra, who has served as chair since 1983, the Humanities Department has become one of WPI's largest (second only to Electrical and Computer Engineering). The highly accomplished humanities faculty includes 25 tenured and tenure-track professors who teach nearly 120 courses in art history and architecture, English (including literature, communications and drama/theatre), history, languages, music, and philosophy and religion.

Recognized for their scholarly accomplishments in a wide variety of fields, the humanities faculty in 1992 published six books and 24 scholarly articles, presented 52 papers at professional meetings, produced 10 creative works, and received several research fellowships and grants. Three faculty members—David P. McKay, professor of music, Thomas A. Shannon, who holds the Paris Fletcher Distinguished Professorship in the Humanities, and Michael M. Sokal, professor of history and former executive secretary of the History of Science Society—are among the recipients of WPI's Board of Trustees' Award for Outstanding Creative Scholarship.

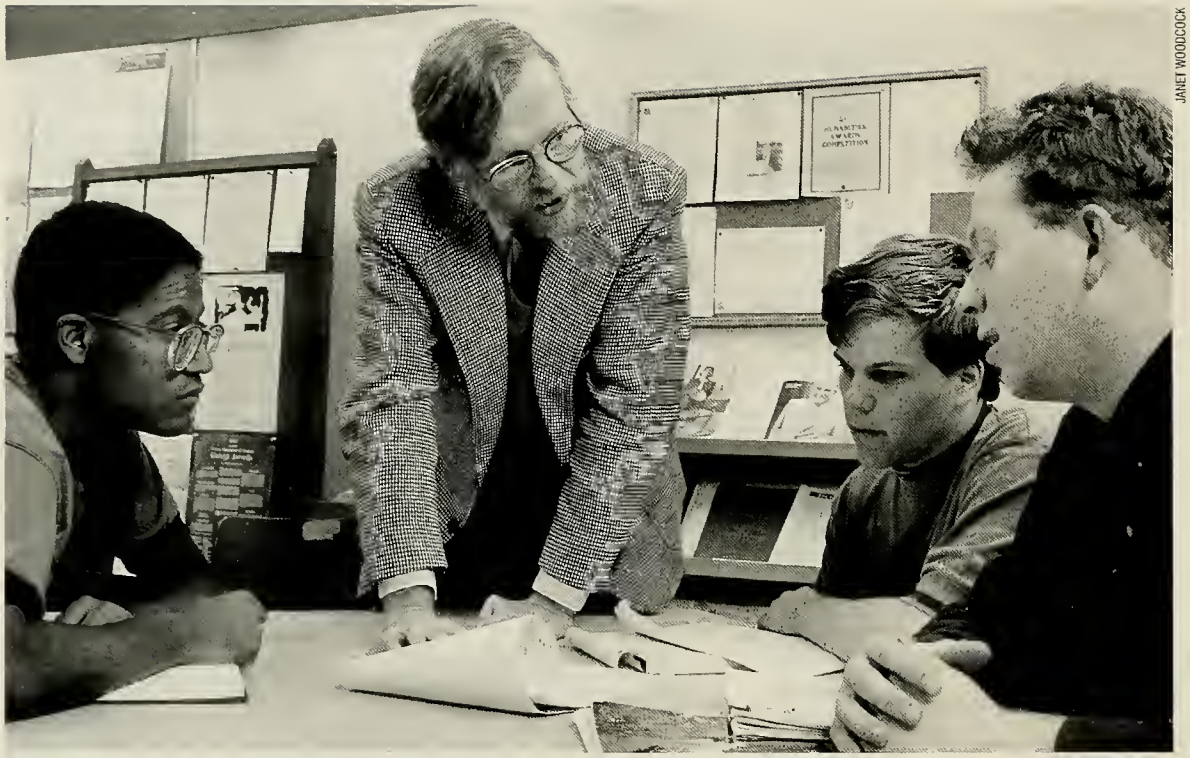
The size of the faculty and the large number of humanities courses reflect the important role played by the department in meeting the goals of the WPI Plan. In particular, the Humanities Sufficiency places a significant demand on the department's resources. Under the Plan, every undergraduate (there are now some 2,700 enrolled) must complete a Sufficiency, and every Sufficiency is advised by a humanities faculty member.

In addition to advising Sufficiency projects, the humanities faculty also plays an important role in the Interactive Qualifying Project, another undergraduate degree requirement. This exercise requires students to explore some aspect of the relationships between science, technology and society. The projects themselves often involve real-life issues that may confront students in their future careers or personal and civic lives as adults.

"By its very nature, the interactive component of the IQP is flexible enough to afford all humanities faculty—whatever their areas of expertise or interest—an opportunity to advise these student projects," Manfra says. "In fact, the faculty has worked with a wide variety of programs and institutions to develop IQP topics and programs."

JANET WOODCOCK

WPI's distinguished Humanities Department, the Institute's second largest, plays a critical role in fulfilling the goals of two of WPI's three undergraduate degree requirements, notes JoAnn Manfra, who has served as department chair for the last decade.



JANET WOODCOCK

Bottom, David B. Dollenmayer, associate professor of German, is using part of a grant from the Daniels Foundation to develop a new language laboratory. Above, W.A. Bland Addison Jr. (standing), associate professor of history and advisor to humanities majors and double majors, meets with, from left, double major Bryant O'Hara '92, humanities major William L. Schongar '94 and double major Ian K. Cote '95.

Many humanities faculty members have advised IQPs at the Institute's residential project centers in Washington, D.C., London and Venice, Manfra says. Others have worked with IQP teams closer to home through the Living Museums Program. Among the institutions that have participated in that program are Old Sturbridge Village, the Higgins Armory Museum and Mechanics Hall. "In one way or another," Manfra adds, "all of our faculty members have contributed to the intellectual content of this unique degree requirement."

The important ties between the liberal arts, engineering and the sciences, which have become evident through the IQP, also form the intellectual foundation for the humanities major and double major, Manfra says. Five students are currently enrolled as humanities majors at WPI. They specialize in one liberal arts discipline—literature, history, or philosophy and religion—and they complete their Major Qualifying Project in that discipline. Recent examples of humanities MQPs include a modern version of the legend of Faust, written by Kelli Sue Clark '92, who specialized in literature, and an examination of the political implications of Buddhism by Glenn W. Flaherty '91, whose specialty was philosophy and religion.

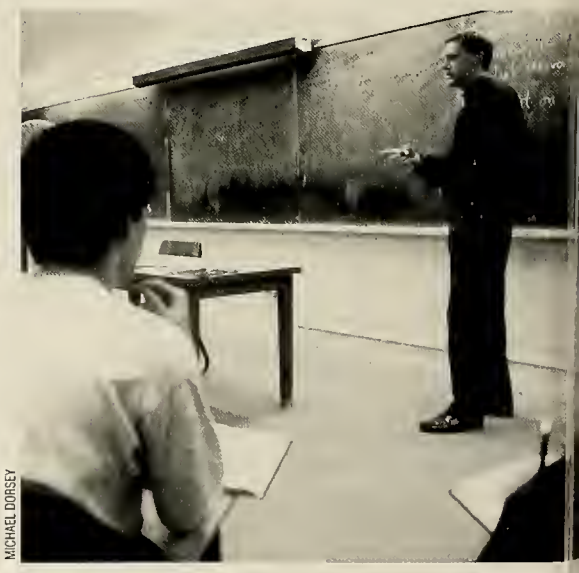
To broaden the context of their chosen specialty, humanities majors also take a cluster of courses in a related area of the liberal arts. And like all WPI undergraduates, they complete an IQP and a Sufficiency project, the latter in one of the engineering or science disciplines or in management.

A growing number of students—15 at present—are pursuing double majors, which allows them to combine their abilities and interests in engineering, science or management with a carefully planned program in the humanities. Double majors must satisfy the degree requirements of both major programs, including the completion of two MQPs.

"Individual and societal concerns are likely to result in increasing demands for specialists equipped with the type of background possessed by a WPI major or double major," Manfra says. "Many fields, including medicine, law, industry, commerce and public service, will be open to those who have acquired both the traditional skills of humanistic education and technical knowledge."

While not every WPI student graduates with such a diverse combination of talents and interests, each will have the opportunity to gain a rich perspective on the world and his or her role in it, much as the Institute's founders had hoped they would, thanks to the dramatic changes humanities instruction has undergone at WPI over the past two decades.

Notes W.A. Bland Addison Jr., associate professor of history and advisor to the humanities majors and double majors, "At WPI, students can develop analytical thinking, writing and expressive skills—and obtain the professional, scientific and technical training to enable them to find jobs—at an institution celebrated for its engineering and scientific accomplishments."



MICHAEL DORSEY

A Delicate Balance

In a world where engineers must understand humanistic issues and nonengineers must be technologically literate, how well does a major or double major in the humanities prepare WPI students for future careers? Let these graduates and current students tell the story. Their successes are testimony to the value of the humanities in engineering education.

Testimony is something **Judge Paul A. Fritzsche '72** knows all about. After receiving his bachelor's degree from WPI in humanities/technology (with an emphasis on history), Fritzsche graduated from the University of Maine School of Law, then worked as a legal assistance attorney. He has been a Superior Court judge in Maine since 1986.

"My unusual undergraduate education proved particularly helpful during my five years as a public advocate, when I represented consumers in public utility regulatory proceedings," Fritzsche says. "The mathematics and science courses I took provided a good background for the engineering, technical and economic issues I dealt with. My humanities courses helped me better explain the issues and the policy choices to the press and to the legislature."

The dual grounding in humanities and science he received at WPI continues to serve him well, Fritzsche says. "As a judge, I deal with a wide range of issues—often involving science and technology—such as product liability, medical malpractice, blood testing, and electronic monitoring of prisoners. These and other issues pertaining to public policy and economic regulation confirm that my WPI education prepared me well for my career."

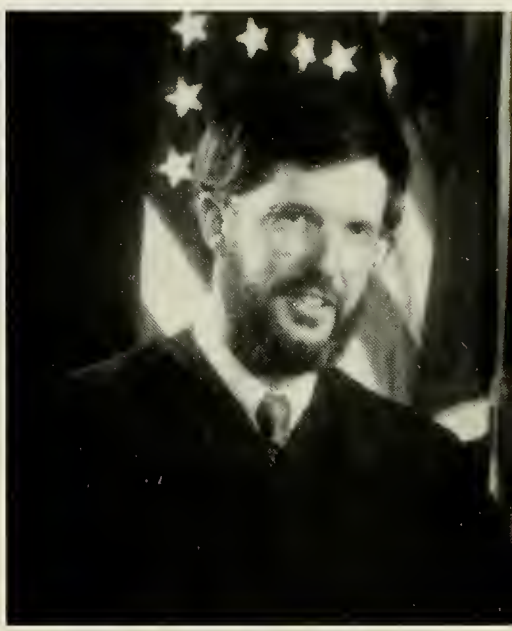
"Science and math without humanities only produces an empty technician," says **Dr. Nancy Berubé '75**, assistant professor of medicine in the University of Massachusetts Medical Center's Department of Family Practice. "Rather than being mutually exclusive, the sciences and the humanities feed and nourish one another. I think it's important to have a balance."

As an undergraduate, Berubé, who received her bachelor's degree with distinction in humanities in 1981, was active in theater at WPI, and worked at Old Sturbridge Village, where she did historical interpretation and acted in OSV's drama program. She drew on her experience at the village for her Major Qualifying Project, a dramatic interpretation of the diary of a 19th century shoemaker.

"I had always intended to go to medical school," says Berubé, who earned her M.D. at the University of Massachusetts Medical Center and now works at an inner-city family health center run by the university. "I'm a big supporter of nonscience majors going into medicine. In order to be a good physician you have to be able to listen to people—to have them tell you what they feel is wrong.

"I think of science as being able to observe something and express it in your own terms," she adds. "The humanities teaches you a different way of doing that. Studying at a school of science and technology gives you a unique perspective on the humanities because it implies you are expected to become proficient in some aspect of the sciences; it gives students a more balanced approach to the humanities."

After earning his degree in humanities/technology with distinction in 1975, **Steven W. Harvey** worked as a district manager for a small record company and participated in a demonstration project that applied an HMO model to providing care for families covered by Medicaid. In 1981 he enrolled at the University of Pennsylvania's Wharton School, continuing his interest in the public sector by working for Philadelphia's finance director. After receiving his M.B.A. in 1983, he worked briefly for Standard and Poors rating municipal bonds. Today he is senior analyst for all of Fidelity Investments' municipal bond funds, with nearly $13 billion under management.



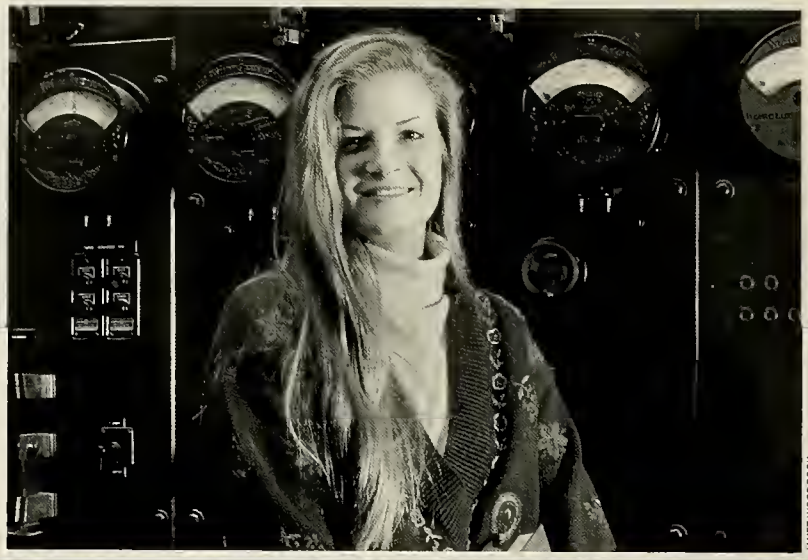
Paul A. Fritzsche '72 says his WPI humanities degree helped prepare him for a career as a judge.

"I continue to find my WPI background invaluable in my day-to-day activities," he says. "My work demands a pretty good grasp of engineering matters as it deals most often with the financing of large public construction projects. I believe, however, that the key to a municipal bond's credit quality—and to its value as an investment—is local or statewide politics; this is the area where my training in the humanities has been particularly useful.

"The ability to communicate, to write well and to get to the point quickly and clearly are also essential to my daily business. I owe my communications skills largely to the individual attention I received from the humanities faculty at WPI."

Like Berubé, **William Katzman '92** became involved in theater as an undergraduate. Before coming to WPI, Katzman had been active as an actor and mime with school or professional theater groups for several years. "I knew I couldn't support myself as an actor," he says. "I came to WPI

MICHAEL OORSEY



JANET WOODCOCK

Left, an interest in the theater drew double major William Katzman '92 to WPI. Above, Kim Philipp '93 will turn her dual major in humanities and electrical engineering into a career in patent law. Below, dual major Raymond Bert '93 served a year as co-editor of the student newspaper.

because it was a small school where I could have a strong major in physics and a strong minor in drama. When I realized I'd probably end up taking almost every drama course the college offered, I decided my transcript might as well reflect that, so I became a double major."

A winner of WPI's Salisbury Prize, Katzman was a member of Masque and MW Repertory Theater, Etc. and a founder of the improvisational group Some Assembly Required. He also wrote three plays as an undergraduate; two were performed as part of New Voices, WPI's annual festival of new plays. For his Major Qualifying Project he wrote an 81-page script for a comedy video. "It was a pseudo-documentary about a person trying to get a film produced," he says.

Since last June, Katzman has been enrolled in the Math, English, Science, Technology Education Project at the University of Massachusetts. The intensive 15-month program offers paid internships in teaching and industry. At the conclusion of the program, Katzman will receive a master's degree in education and will be certified to teach high school physics. Graduates are asked to make a commitment to teach for a minimum of three years after they complete the program.

"You benefit from coming out of an engineering school with a humanities degree," he says. "A lot of companies want humanities majors for business positions. At WPI, you get some technical elements because the projects involve technology. It isn't easy. You have to be able to do this stuff. They don't teach 'Calculus for Poets!'"

While the Institute attracts a few students who enroll specifically to be humanities majors, most, like **Nikolai A. Yurkanin '95**, switch their major to humanities from engineering or science. Yurkanin, who says he was heavily involved in the science program at his high school in Holden, Mass., and won awards at science fairs, came to WPI to study engineering, but had a change of heart after taking introductory courses in science and math.

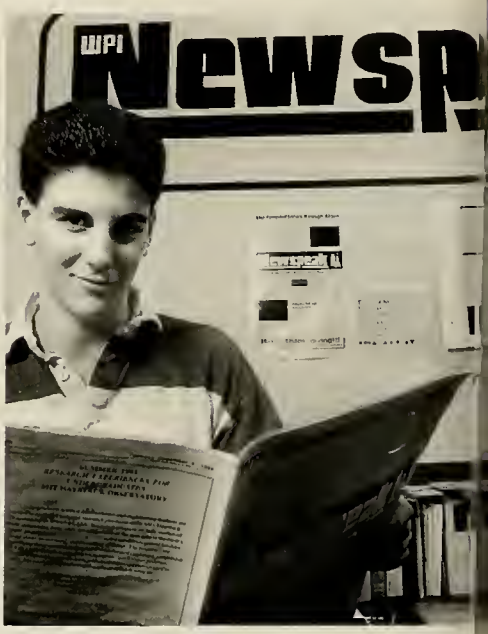
"I really enjoyed my humanities courses—especially 'Light and Vision,' which examines the arts from the perspective of physics, chemistry and biology. I thought, 'Wow, I wish I could do that!'"

One of the advantages of being a humanities major at WPI is the opportunity to get a feel for science and technology as well as liberal studies, notes Yurkanin, who says he aspires to design exhibits for the Smithsonian Institution after graduation. "You get a really good perspective when you take the kinds of courses available at a school that specializes in science and engineering."

For **William L. Schongar '94**, the humanities proved an attractive option after he realized that his original career choice, aerospace engineering, wasn't for him. "After a year and a half, I knew I didn't want to crunch numbers the rest of my life. My mother is an English teacher and I like to write, so I decided to major in the humanities."

Schongar, who calls himself a medievalist, completed his Interactive Qualifying Project at the Tower of London. After surveying visitors to gather information that will enable the administrators of the tower to improve their displays, Schongar decided he'd like to create exhibits for the Higgins Armory Museum in Worcester. "I like to teach people, and one of the best ways to do that is to write about what they are going to see, giving them information to work with."

Raymond R. Bert '93 and **Kimberly S. Philipp '93** both became double majors after discovering the range of courses offered by the Humanities Department. Bert, who is majoring in mechanical engineering and hu-



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manities, says that while he's always had an interest in the humanities—particularly writing—he enrolled at WPI to study engineering.

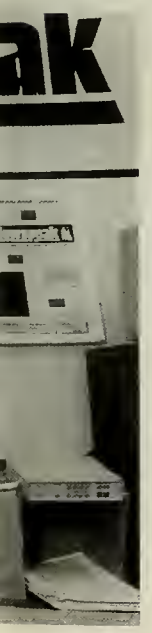
As a sophomore, he fulfilled his Sufficiency requirement with a project on Stephen Crane. "That's when I learned about the humanities major," he says. "I like the idea that it's somewhat free-form, with everything leading you toward your MQP."

His focus in the humanities being nonfiction writing, he joined the staff of *Newspeak*, the student newspaper, during his junior year. After serving as associate editor, he became a co-editor in January 1992; he completed his term in December.

Bert's mechanical engineering MQP focused on resident stress effects on the fracture toughness of ceramics; for his humanities MQP he is assembling a portfolio of his own original news articles. "People are surprised when they hear I'm doing a double major—and that one of those majors is in a nontechnical field," he says. "But majoring in the humanities and mechanical engineering doesn't pose a particular challenge for me. It allows me to study two things I really enjoy."

Though he plans to work in materials science after graduation, Bert says, "I'd like to see myself as some sort of writer someday, perhaps as a free-lancer for a newspaper."

With her dual major program, Philipp is studying history and electrical engineering. The daughter of an electrical engineer, she enrolled at WPI with the intention of following in her father's footsteps. "I'd always had an interest in history and law and I originally planned just to do a regular Sufficiency in those areas," she says. "I decided on the double major after I took a legal history course with Professor Manfra, who talked about the humanities major in class."



Philipp incorporated her growing interest in law and the legal aspects of history into her Interactive Qualifying Project. Working at the Washington, D.C., Project Center for the United States Patent Office, she and her teammates researched maintenance fees applied over a 12-year period.

As she approaches the completion of her dual-degree program, Philipp has decided she won't be a second-generation electrical engineer after all. After graduation she plans to take her law boards and apply to law school to become a patent attorney.

—Bonnie Gelbwasser

The Humanities: Up Close and Personal

It seems that for as long as colleges and universities have been preparing young men and women for careers in science and engineering, educators have been discussing how best—and how extensively—to expose these technically oriented students to the arts and humanities. It was a subject that stirred debate 100 years ago when the American Society for Engineering Education was founded, and it is one that still has people talking and writing today.

Despite all the debate, most educators agree that to be fully prepared to meet the demands of their professions, scientists and engineers need much more than an introduction to the humanities and the arts. "It's part of our culture, our intellectual heritage and our environment," notes Lance Schachterle, associate dean of undergraduate studies and professor of English.

"It is critical for all students—regardless of their professional background—to be well-grounded in these fields, just as it is critical for students in the humanities to be well-grounded in science, math and technology. It's fundamentally important to intellectual development and to stimulating students' native curiosity to provide them access to all the achievements of our culture—scientific, artistic and otherwise."

Schachterle also notes that from a practical view, a firm foundation in the humanities can give a scientist or engineer an edge should he or she—as many technical professionals do during their careers—enter the world of management. "It is still typically the case that people in high government positions and those high on the corporate ladder have backgrounds in the humanities," he says. "If people trained in science and engineering are to rise equally high, they must know something about the intellectual substance of their competition."

Surprisingly, considering all the years of soul-searching about the humanities, most U.S. engineering programs have settled on a fairly standard and prosaic approach to the field. Most adhere to guidelines published by ABET, the Accreditation Board for Engineering and Technology, which stipulates that accredited programs require students to take a total of one-half year's worth of courses (usually selected at random) in both the humanities and social sciences.

And that was how the humanities was handled at WPI up through the late 1960s, when the faculty and administration began a critical appraisal of the WPI curriculum that ultimately resulted in the WPI Plan, a dramatic departure from the traditional "boot-camp" approach to engineering education. One of the innovative elements of the Plan was a novel way of introducing students to the humanities and arts called the Humanities Sufficiency program.

While most engineering schools have settled for a "Chinese menu" approach, in which students fulfill set distribution requirements by choosing one or more courses (usually at the introductory level) in several areas of the humanities, the designers of the Plan, through the Sufficiency, developed a different model, one that emphasizes depth rather than superficial exposure to the entire range of disciplines.

"The Sufficiency degree requirement is designed to offer students a 'sufficient' liberal arts experience," notes JoAnn Manfra, head of the Humanities Department. "Its goal is to provide students with a more than

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According to a study designed by James Hanlan, associate professor of history, the Humanities Sufficiency provides WPI students with a worthwhile intellectual experience that few, if any, of the Institute's competitors can match.

passing acquaintance with a field unrelated to engineering or science. More profoundly, perhaps, the Sufficiency program attempts to demonstrate that being educated means embracing valid, intellectually vigorous ways of examining knowledge in which there is a role for ambiguity—both 'factual' and 'moral.' In other words, the Sufficiency experience provides a healthy dose of disciplined thinking about uncertainties."

To fulfill the Sufficiency requirement, students must take five thematically related humanities courses and then complete an original project that draws on the material in those courses. The combination equals about a half-year of work—the amount ABET requires engineering students to devote to both the humanities and social sciences. WPI students must also take two courses in the social sciences and complete the Interactive Qualifying Project—the equivalent of another three courses.

Students may not work in teams on their Humanities Sufficiencies, which are usually done during the sophomore year, so every student must be individually advised by a humanities faculty member. On average, each humanities professor advises 26 Sufficiencies a year.

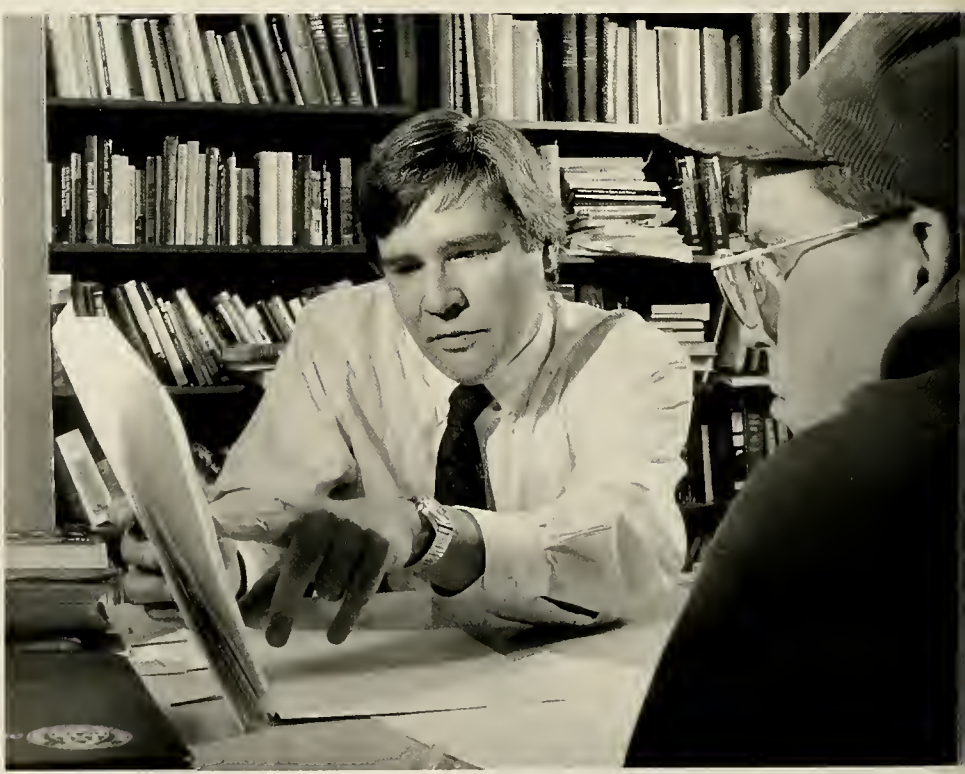
Since the range of topics for the Sufficiency can be as broad as the disciplines that make up the humanities and the arts, the department has endeavored to provide considerable diversity in its course offerings, Manfra says. Students may supplement the department's offerings by taking courses at other colleges in the Worcester Consortium for Higher Education, including such noted liberal arts institutions as Holy Cross College and Clark University.

A student generally begins work on the Sufficiency by developing an idea of what he or she would like to accomplish in the final project. The possibilities are surprisingly broad. Often the final product is a paper or critical essay, but students may also choose to write an original work of fiction such as a short story, a collection of poems or a play, or create an original musical composition. Students may also undertake a musical or dramatic performance and then write an essay about their experiences.

Some students complete the Sufficiency by taking six courses in a foreign language or by taking part in the American Studies Seminar, a series sponsored each fall by the American Antiquarian Society in collaboration with five Worcester colleges and universities. Seminar topics focus on areas that let students make full use of the extensive holdings in American history, literature and culture housed in the society's headquarters, located adjacent to the WPI campus.

A student develops and hones his or her theme in consultation with a faculty advisor; the advisor continues to work closely with the student as the Sufficiency progresses. With a theme in mind, the student then chooses the five courses he or she thinks will provide the proper intellectual underpinnings for the project. Although these courses may fall within a single area of the humanities, interdisciplinary work is encouraged. The only requirement is that material presented in the courses be related to the Sufficiency theme.

There are no hard and fast rules for mak-



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English Professor Kent P. Ljungquist, left, and Philip E. Marks '93 review a draft of Marks' Sufficiency project on literary impressionism in the works of Stephen Crane.

ing these choices; often the courses chosen present a surprising and thoughtful tableau. Here are two examples from projects completed in recent terms:

"Childe Hassam: An American Impressionist"

A look at the works and influence on the world of American art by Hassam, a major American painter.

By Julie A. Driscoll '94

Advisor: David M. Samson, assistant professor of art history/architecture

Courses taken:

- Introduction to Art History
- Topics in 19th and 20th Century Architecture
- Modern Art
- Introduction to Painting
- Light and Vision

"U.S. Policy Towards Korea: 1945-1950"

Looking at American and Soviet interests in Southeast Asia, this study outlines U.S. policies that led to the Korean conflict.

By Won Tae Yang '94

Advisor: James P. Hanlan, associate professor of history

Courses taken:

- Introduction to Philosophy and Religion
- American History: 1877-1920
- The Shaping of Post-1920 America
- Introduction to the Study of Foreign Policy and Diplomatic History
- American Foreign Policy from Woodrow Wilson to the Present

Does the Sufficiency accomplish its goals? To answer that question, last June six humanities faculty members sat down to read and critique nearly 300 Sufficiencies completed during the 1991-92 academic year. "The reviewers were generally impressed with the quality of the student work," says James Hanlan, who designed the study and analyzed the results of the evaluations. "While a few papers could be described as run-of-the-mill, most were clearly worthwhile intellectual experiences of the sort few, if any, of our competitor colleges offer their students."

The Sufficiency Review Committee made some recommendations for strengthening the program, nearly all of which have been implemented, Manfra says. "This is a strong program, but we didn't just design it and leave it alone. Our faculty are continually revisiting the Sufficiency program to find ways to enable it to fulfill its objectives."

Recently, the humanities faculty developed a new off-campus option for the Sufficiency program. It will allow undergraduates to complete work toward their Sufficiency during a seven-week period outside the bounds of the campus. A student writing about the French Revolution, for example, might study original documents and visit historic sites while he is in residence at the University of Marne-la-Vallée in Paris, with which WPI runs an exchange program. A playwright might travel to the Edinburgh Arts Festival in Scotland to experience the leading edge of theater, or even to see her own play performed.

"Sufficiency projects undertaken in international settings will encourage students to immerse themselves in the intellectual traditions of other cultures," Manfra says. "Similarly, projects done at off-campus project centers in the United States will introduce students to cultural diversity here at home."

Another measure of the success of the Sufficiency program is the fact that ABET, the major accrediting agency for all engineering colleges, has recently revised its guidelines for humanities education, notes Francis C. Lutz, dean of undergraduate studies.

"In the most recently published criteria for evaluating engineering programs, ABET made a point of emphasizing that the courses students select must provide not only breadth, but depth," he says, "and not be limited to a bunch of unrelated introductory survey courses. It's taken more than 20 years, but it looks like the profession may finally be recognizing that our approach does a much better job of preparing students to be solid professionals and competent citizens."

—Michael Dorsey

Helping Students Find the Right Words

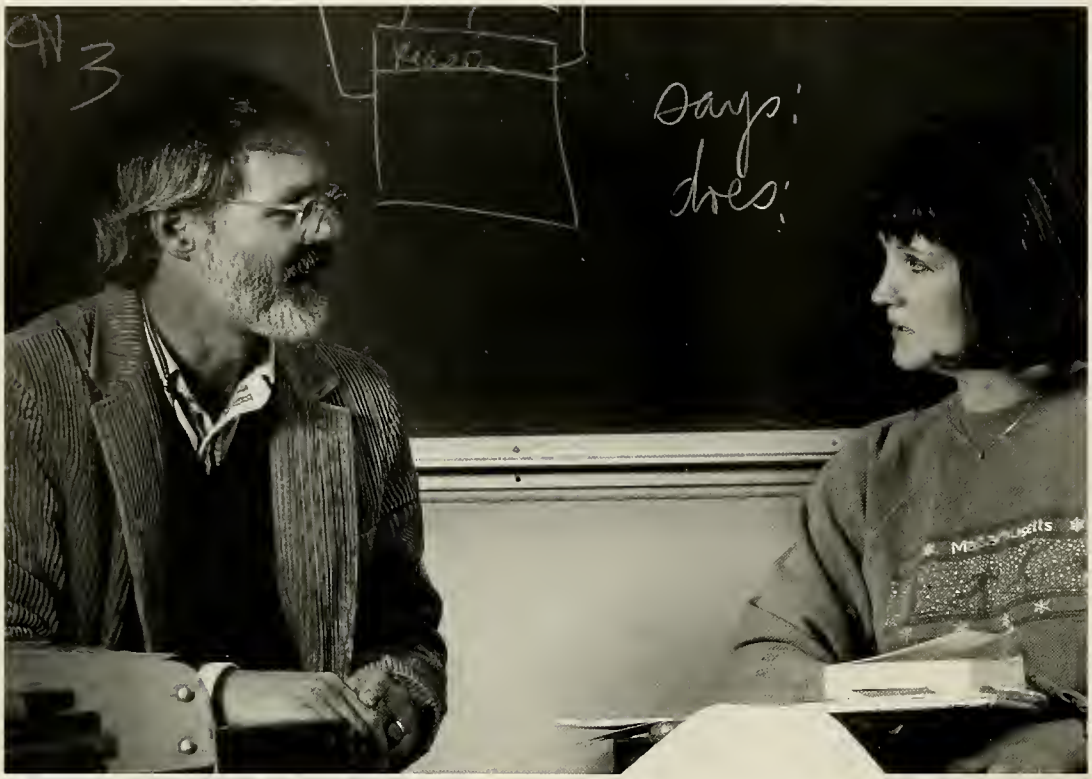
Anyone who's ever struggled to compose a thank-you note or a thesis can appreciate Fowler's words. But for WPI students, finding the right words has gotten a bit easier, thanks to the efforts of the Humanities Department and other educators at the Institute, who've worked over the last five years to develop a variety of writing education and tutoring programs.

"Writing is easy. All you do is stare at a blank sheet of paper until drops of blood form on your forehead."

—Gene Fowler

The process began in 1988 when John M. Trimbur, associate professor of English, was hired to develop a writing program and expand the Institute's course offerings in writing. A writing specialist with a background in rhetoric and composition, Trimbur asked William R. Grogan, now dean emeritus of undergraduate studies, to form a committee to oversee the writing program.

Today, the Writing Advisory Committee promotes the importance of oral and written communication and develops programs to integrate writing across the entire undergraduate curriculum. Trimbur chairs the committee, whose members are Herbert Beall, professor of chemistry, David DiBiasio, associate professor of chemical engineering, William Farr, assistant professor of



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John Trimbur, associate professor of English, discusses a writing assignment with humanities major Teran Sacco. A writing specialist, Trimbur directs a variety of programs aimed at preparing some WPI undergraduates for careers in writing and helping all students communicate more effectively.

mathematical sciences, Thomas Keil, professor of physics, and Judith Miller, associate professor of biology and biotechnology.

Here are some of the programs that the committee now helps oversee:

Writing Across the Curriculum does just what its name implies: it aims to make writing (and speaking) an important part of every course taught at the Institute. To date, the program, which was initially funded with a grant from the General Electric Foundation, has been implemented in lower-division mathematics and science courses. It encourages students to use writing to promote learning and to connect writing and critical thinking.

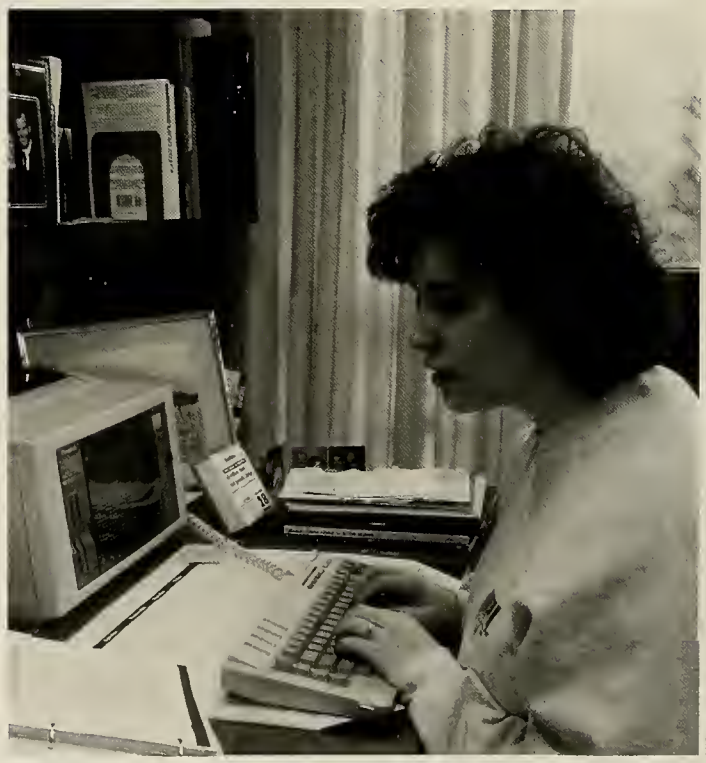
"We assumed that students in their first two years at WPI receive practice in writing in their humanities courses," Trimbur says. "But to prepare them to do the technical or scientific writing called for in WPI's required projects, we needed to develop more opportunities for them to write as part of their math and science assignments."

Trimbur says the Writing Across the Curriculum project has been successful in increasing the number of faculty presentations and publications on the use of writing in the teaching of mathematics and science. For example, Beall and Trimbur have developed a booklet of reading and writing assignments called *Reading and Writing in Chemistry* and have conducted faculty workshops to assist other faculty members in assigning writing projects to their classes and responding to the work their students do.

Last spring WPI, Clark University and Holy Cross College sponsored the Second Annual Writing Across the Curriculum Conference, the theme of which was "Science and the Postmodern World." Also last year, Beall organized WPI's Sixth Annual Conference on Chemical Education around the theme, "Writing as a Tool to Teach Chemistry."

Tutors at WPI's **Writing Resource Center** offer writing assistance at no charge in any academic area—from papers to project reports—and are available to help students with any other writing or writing-related work, such as resumes or graduate school and job applications.

The center, located in Salisbury Laboratories, was established in 1975 to assist students with project work; it gradually evolved into a resource used primarily by international students. Since 1991, when Barbara L. McCarthy was



MICHAEL OORSEY

Technical writing major Renée LaFountain says her WPI education gave her an excellent grounding in both writing and science.

named director, the center has broadened its scope to meet the writing needs of all WPI students.

Last spring, Trimbur and McCarthy inaugurated an independent study titled "Peer Tutoring in Writing." Those who complete the course are offered jobs at the center. "The philosophy behind peer-tutor training is that students respond better to suggestions from fellow students than from faculty," says McCarthy, who notes that tutors also hone their own writing skills by teaching others. "The increasing numbers of undergraduates who take advantage of our services appear to bear this out.

"This is not a drop-off editorial service," McCarthy adds. "Although most students come to the center for help with a specific assignment, we don't just correct their writing. We want them to become writers, and we encourage them to interact with us. Professors are demanding improved writing skills in the papers they assign and in the projects they advise. Instruction in writing can benefit all students, not just those for whom English is a second language."

WPI's **Technical Writing** major is administered by the Institute's Interdisciplinary Studies Division. Its current directors are Trimbur and Stephen J. Weininger, professor of chemistry.

It was Barbara O'Toole '88 who blazed the trail for today's technical writing majors. In her third year as a mechanical engineering major, O'Toole decided that her interests lay more in writing about technology than in developing technology. Trimbur developed an intensive technical writing program for O'Toole, who graduated as an interdisciplinary major. She is now employed as a technical writer at Stratus Computer Inc. in Marlboro, Mass.

"I document communications software and hardware," she says. "The manuals I write consist of programmers' guides, network and configuration and administration guides, and general product bulletins. I also use a lot of my computer-aided design course work as I produce graphics and illustrations for these manuals."

Technical writing became an official major in 1990; 15 undergraduates are currently enrolled in the program. Majors take half their courses in writing and half in a technical or scientific concentration. The writing concentration consists of all three of WPI's writing courses—Elements of Writing, Nonfiction Prose and Writing in the Professions—plus three independent studies—Composing Theory and Research, Rhetorical Theory, and Peer Tutoring in Writing.

"Because of the interdisciplinary nature of the program, our students have a strong technical and scientific background," Trimbur says. "They are well-prepared to work in a variety of areas, including publishing, science journalism, or hospital or museum public relations."

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From top, in WPI's Writing Resource Center, writing tutor Kathleen M. McKenna '94 reviews a paper with Ly C. Chhem '95 while center director Barbara L. McCarthy, instructor of communications, reviews a tape of a public speaking assignment with Alex Cardenas '96, a native of Panama.

Senior Renée LaFountain of Gansevoort, N.Y., is one of the new crop of technical writing majors. Like O'Toole, she didn't start out to be a writer. "I came to WPI for the science, math and engineering programs and ultimately decided to major in biology," she says. "By the time I realized biology was not where I wanted to spend the rest of my life, I had become quite involved in the school. For me it was just a matter of finding a program that fit."

LaFountain, who plays piano and trumpet, is president of WPI's student jazz program. After completing her Humanities Sufficiency requirement on jazz in the 1950s and her IQP on transgenic animals and their use in research, she realized how much she had enjoyed writing and organizing the projects. When she learned she could complete the degree requirements for a technical writing major and still graduate on time, she made the switch.

Trimbur says WPI is particularly well-equipped to educate students like LaFountain. "Most technical writing programs come out of English departments," he says. "While those students take the same number of courses in writing as ours do, they don't have nearly the depth in a technical or scientific field. We've had a lot of positive feedback from employers, who tell us that our students are much more fluent in engineering and science than those who've been educated at liberal arts colleges."

"I'm still a scientist at heart," says LaFountain. "When I learn about something going on in biological research, for example, I understand it from a scientist's perspective. The challenge for me as a technical writer will be to take that highly scientific information and translate it into terms the average person can understand."

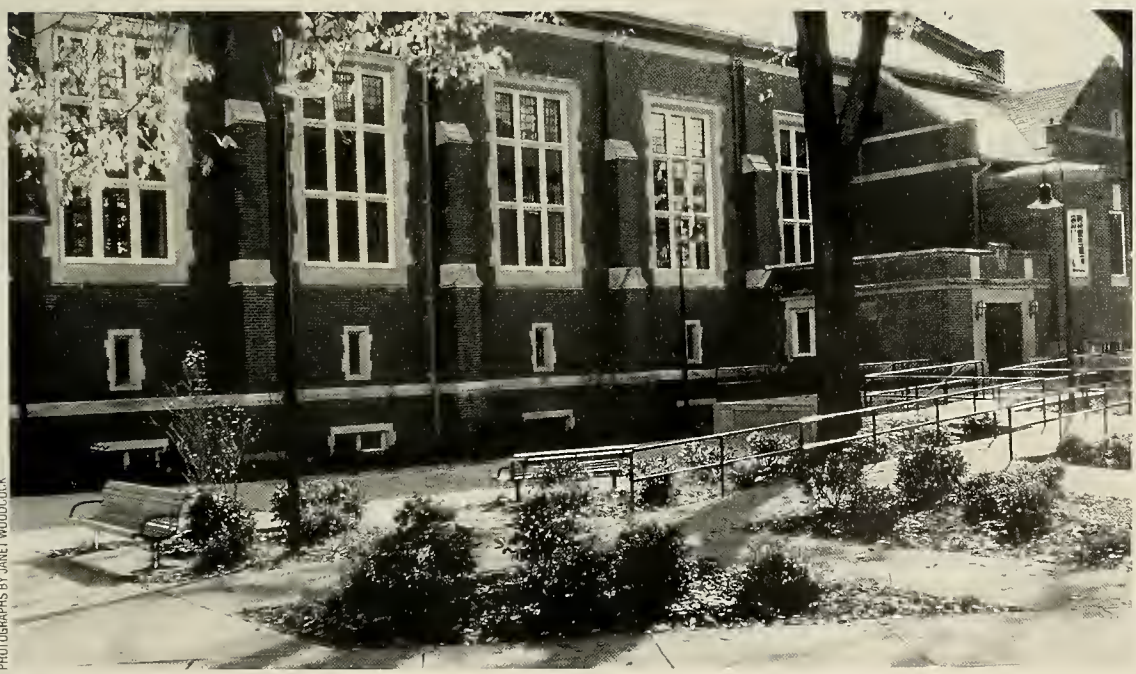
As she starts to look for a job, LaFountain says she feels "really marketable. I have a strong science background and I can write. I believe I can compete favorably against technical writers who are humanities majors and who've only taken introductory science courses, as well as against scientists who've never learned about writing. It's the best of both worlds."

—Bonnie Gelbwasser

Alden Reborn

For 50 years, Alden Memorial has served as a social and cultural center for the WPI community. After a yearlong restoration, this gem of a building has emerged as a modern center for the performing arts. Now, from early morning until late at night, the halls are alive with the sound of music—and drama.

By Michael Dorsey



PHOTOGRAPHS BY JANET WOODCOCK

November 19, 1992. 7:30 p.m.

Backstage in Alden Memorial, students line up before long, lighted mirrors in two new dressing rooms, putting on stage makeup and getting into costumes. In a half hour they'll be on stage, as a high-tech explosion of lights, video projections, music, sound effects, fog and smoke heralds the opening of an imaginative production of Shakespeare's *The Tempest.*

November 24, 1992. 7:00 p.m.

Walking down the corridor of Alden's lower level, a visitor is enveloped by the sound of young voices. Lining the risers in the Janet Earle Room, the 50 members of the Men's Glee Club practice a demanding arrangement of *Greensleeves.* Across the hall in the Perreault Chamber Rehearsal Room, the Women's Chorale warms up with a medley of Christmas songs.

December 1, 1992. 1:45 p.m.

In Alden's new music classroom, Professor David McKay is reviewing a lesson for students in his course on the fundamentals of music. Seated at the piano, McKay guides the class through the finer points of harmony.

December 3, 1992. 7:35 p.m.

As late arrivals search for seats on the floor of the great hall and in the balcony, the Concert Band strikes up a festive tune, beginning the annual holiday concert that will showcase most of WPI's 15 musical groups.

Some 52 years after it was built, Alden Memorial has gotten a new lease on life. Designed to fill the need for a multipurpose auditorium on campus and to provide a home for a central library, the building has been transformed into a modern and elegant center for the performing arts.

The transformation, in the planning stages since 1984, began just after Reunion in 1991 and was completed in time for Commencement in 1992. In addition to these activities, the renovated building has since hosted numerous events and meetings, including a special series of concerts and plays designed to showcase its new spaces and facilities. The various events were sponsored by the Applied Music Division, Masque (the student dramatic arts society) and the Social Committee, or SocComm.

But despite the nearly constant activity in Alden since it reopened, the building will not be officially rededicated until April 22, 1993, the 150th birthday of its namesake, George I. Alden (see Advance Word, page 2). On that day the members of the newly formed George I. Alden Society, a recognition group that honors alumni and friends who have included WPI in their wills or estate plans for at least $25,000, will enjoy a dinner and an address by Richard H. Gallagher, president of Clarkson University, former WPI provost and a pioneering researcher in the field of finite element analysis. Donors to the restoration, special friends and selected members of the WPI community will also be invited to the event.

The $2.7 million restoration, designed by the firm of Shepley, Bulfinch, Richardson and Abbott in Boston and completed by general contractor Cutler Associates in Worcester, was largely funded by a $1.6 million grant from the George I. Alden Trust, which gave the building to the college in 1940 as a permanent memorial to Alden. Other generous gifts were received from the Surdna Foundation, the George C. Gordon Trust, the Daniels Foundation, and a number of alumni and friends (see box, page 21).

Opposite, under the direction of Margaret M. Konkol, the Women's Chorale performs during the annual holiday concert in the fully restored great hall of Alden Memorial. Above, Erica A. Curran '96 and Byung S. Yun '93 take advantage of new private rehearsal rooms.

The Alden Memorial project combined careful restoration of what has been called one of the most beautiful college buildings in the Northeast, with the creation of new spaces and facilities for music and theater. Even before entering the building, one notices a major change: a new, spacious freight elevator that serves each of its four levels and the stage. A small extension was added at Alden's southwest corner to accommodate the elevator; due to a careful choice of brick and the reuse of original limestone cornices and moldings, the extension's facade is nearly impossible to distinguish from the original construction.

Adjoining the extension is a new loading dock that makes it easier to deliver supplies and equipment to the building, a handicapped access ramp, and a new plaza linking Alden to the adjacent Sanford Riley Hall (see photo, page 15). The Class of 1942 earmarked $100,000 of its 50th anniversary gift for the construction of the plaza and used another $25,000 to set up an endowed fund that will ensure the plaza's maintenance in the years ahead.

Entering Alden on the main level, a visitor might almost fail to notice the results of the restoration, for in many ways the foyer and great hall look much as they did when the building was completed in 1940. But a more careful examination reveals the products of a loving

Above, Susan Vick, professor of drama/theater, gives the cast and crew of *The Tempest* some final comments in the greenroom before the curtain rises on dress rehearsal night. Opposite, from left, graduate student Andrew L. Hansford, Kristi J. Henricksen '94 and Hollybeth Normandin '94 in a scene from *The Tempest*. Below, Douglas Weeks, director of applied music, directs the Concert Band as it performs in the new Lora E. Spaulding Recital Hall, one of the new performing arts facilities in Alden.

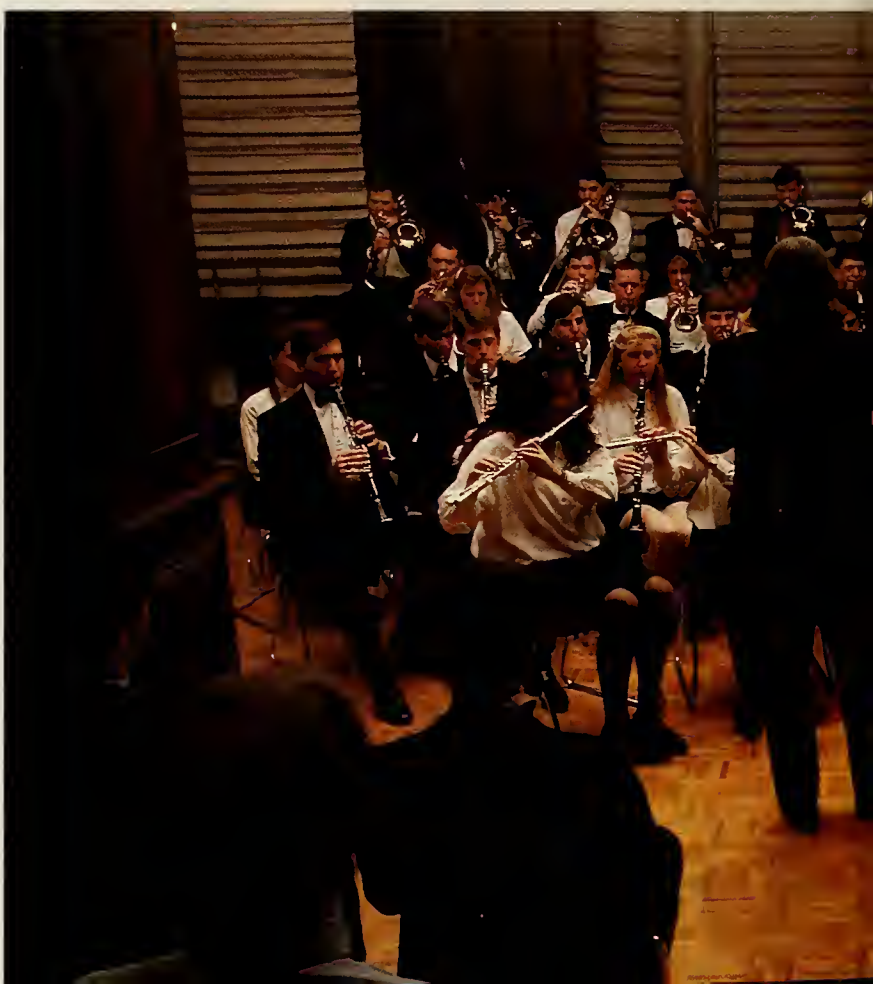
restoration: the refinished marble staircase, the new hardwood floor, the plaster ceiling that replaced the old pressed-straw tiles, the refinished oak paneling and ceiling beams, and the carefully cleaned and restored iron chandeliers and stained glass window medallions.

The great hall is also brighter, thanks to new lighting fixtures (these include new sconces that illuminate the stone carvings at each end of the ceiling beams). Like the rest of the building, the hall has also benefited from upgrades to the plumbing, heating and ventilation systems. There are also new stage and window curtains, new seating for 600 on the floor and 100 in the balcony, new sound-absorbing panels at the rear of the auditorium, a new acoustic shell with an adjustable ceiling, and a new electronic dimmer system and sophisticated pulley system for the stage.

Behind and adjacent to the stage are two new dressing rooms, a room for use by caterers (the auditorium will continue to host dinners and other catered events), and a fully restored greenroom, which serves both as a theater classroom and a place for performers to relax before going on stage.

One floor up, the offices of the music and theater faculty—in rooms that were originally rented to bachelor professors—have also benefited from a thorough face-lift. But to see the most dramatic evidence of the building's transformation, one must travel down to the lower levels.

On the ground level, a once dark, musty storage area has been turned into a brightly lit and well-



equipped scenery construction shop. This level also serves as storage space for the lighting and audio equipment used by Lens and Lights, a student group that provides lighting and sound services for the campus community. The scene shop is served by the new elevator, making it possible to bring flats and other set pieces right to the stage; previously, it was necessary to either build sets on the stage or carry the pieces up two long flights of stairs.

The floor just below the auditorium, long used as practice space by the college's musical groups, has been beautifully redecorated and rearranged to create a highly functional music education, rehearsal and recital center. With the addition of a set of risers, the Janet Earle Room has become the primary choral rehearsal room. Nearby, what was once an unfinished storage room has been turned into a music classroom.

The former Alumni Conference Room at the southeast corner of Alden is now the Ina Perreault Chamber Rehearsal Room. At the southwest corner, in a room that once served as a librarian's office, is a new computer-assisted music laboratory equipped with Macintosh computers, synthesizers and recording equipment. Adjacent to the front stairwell are an office and three new private rehearsal rooms, where students can practice their instruments without disturbing other building occupants.

The centerpiece of this new music center is the Lora E. Spaulding Recital Hall, located in what was originally the college library. In addition to a new wood floor, elegant curtains and refinished woodwork, the addition of risers, sound-absorbing panels and a grid of spotlights make this an ideal performing space for chamber groups. Lora Spaulding, the daughter of Ralph Spaulding '09, left the Institute a major unrestricted bequest in 1989, part of which was used to create this hall.

With its new look and new spaces, Alden is now home to the college's music and drama programs—both educational and extracurricular. (It has also attracted the attention of regional performing arts groups—the Worcester Orchestra will hold a concert in Alden in May.) The Institute's five full- and part-time instructors of music—Douglas G. Weeks, administrator of applied music, Louis J. Curran Jr., associate professor of music, Richard G. Falco, director of jazz studies, Margaret M. Konkol, director of the Women's Chorale, and David P. McKay, professor of music—teach a wide range of courses in music theory and history and advise dozens of student projects each year, including Humanities Sufficiencies that focus on music or include a musical composition or performance.

Nearly all of the music faculty members also direct music groups. In recent years these well-traveled groups have made tours of Canada, Europe, Russia and Africa, in addition to their regular performances at WPI and at other colleges and universities. In 1992, for example, the Concert Band, Brass Ensemble, Stage Band and Jazz Ensemble toured Egypt, a trip that included a breakfast performance before the Sphinx and the Pyramids of Giza for the French and American ambassadors, the governor of Cairo and the mayor of Giza. At the same time, the Men's Glee Club performed in Great Britain, singing at Oxford University, Worcester Cathedral and before over 1,000 people in the Bethlehem Chapel in Rhos, Wales, where they were the guests of the Orpheus Male Choir, one of the most outstanding choral organizations in Great Britain.

A total of 215 students participate in the college's musical groups, Weeks notes. In addition, a number of Men's Glee Club alumni perform with female singers from the WPI community and other colleges as the University Chorus. "WPI's music groups enjoy a long and

Left, Louis J. Curran, professor of music, leads the Men's Glee Club through a rehearsal in the refurbished Janet Earle Room, which now serves as the primary choral rehearsal room. Below, clockwise from bottom, Matthew J. Calistro '96, Jason E. Macierowski '96 and Theodore L. Dysart '94 use the synthesizers and Macintosh computers in the new Computer Music Laboratory.

distinguished history," he says, "but I think it's safe to say that their popularity today is unprecedented. With the restoration of Alden, we now have a beautiful performing arts center that will enable us to further expand our programs and reach new levels of excellence."

Equally as popular as the college's music programs are its continually growing programs in theater. Under the direction of Susan Vick, professor of drama and theater, Masque, one of the oldest student clubs at WPI, mounts a major production each fall.

In 1992, the Masque production of *The Tempest* played to record houses four nights running. In fact, on Friday and Saturday nights, after the regular seats on the stage were all taken (to create a more intimate experience, audience members sit on an extension of the stage at Masque productions), latecomers willingly filled the balcony to watch the play from a less than perfect vantage point.

Enthusiasm for the dramatic arts at WPI seems to grow in intensity each year, says Vick, who notes that about 125 students were directly involved in the production of *The Tempest*, while many others in several student organizations served as ushers, ran a cafe and performed music before the show.

Helping fuel that excitement is an annual festival of original, student-written and -directed plays called New Voices. Now gearing up for its 11th season, New Voices was launched by Vick as a response to a ground swell of interest in playwrighting among WPI students. Now, each January a team of five student dramaturges reviews some 50 scripts submitted by members of the WPI community (mostly students) to choose 15 or so for the April production. Ultimately, more than 400 students will be involved in the 1993 New Voices as directors, actors, stage managers, crew members, publicists, and so on, Vick notes.

Excitement about theater at WPI has grown to the point where one dramatic arts group can no longer contain it, Vick says. Since 1989, MW Repertory Theater, etc., WPI's version of an "off-Broadway" theater group, has been producing two plays a year at various locations on campus. Chain Link Fence, an improvisational theater group, also performs regularly. Another student group mounts productions during the summer months, and the members of Alpha Psi Omega,

The Major Donors to the Alden Memorial Restoration

The George I. Alden Trust

Estate of Lora E. Spaulding, daughter of Ralph E. Spaulding '09
• Recital Hall •

The George C. Gordon '95 Trust
• Stage and Fittings •

George W. Smith Jr. '15
• Greenroom and the Janet Earle Room •

Class of 1942
• Plaza and Plaza Endowment Fund •

The Surdna Foundation
• Computer Music Laboratory •

The Daniels Foundation
• Equipment for Computer Music Lab •

Mary Knight, widow of Frederick H. Knight '28
• Music Classroom •

Ina W. Perreault, late wife of Raymond J. Perreault '38
• Chamber Rehearsal Room •

Joseph Glasser '35
• Performers' Dressing Rooms •

Lilla Molder
• Practice Room •

Richard Prouty
• Practice Room •

Members of several WPI musical groups pose before the Sphinx and the Pyramids of Giza during a 1992 tour of Egypt, one of several overseas trips made by the Institute's music and theater groups in recent years.

the dramatic honor society, help in all of these productions.

Like the Institute's music groups, Masque has also developed a distinctly international flavor in recent years. Since 1988, the group has made frequent treks to the Fringe, part of the Edinburgh Arts Festival in Scotland, the largest gathering of its type in the world. In the summer of 1991, Vick and 30 students performed two plays from the annual New Voices festival for audiences at the Fringe.

"This is one of the best things we've ever done," Vick says. "It is exciting for students not only to experience the best the world theater has to offer, but to see their own work with an international perspective."

The growing interest in activities, courses and projects that revolve around music and theater has led many at the Institute to wonder how those interests might intersect with other academic programs. "As we search for ways to develop our curriculum to respond to what the real world is doing—particularly the downsizing of the defense industry—it will be increasingly important for WPI to provide programs that combine the study of an appropriate technology, like electrical and computer engineering, with a rich immersion in music and theater, leading to careers in growing fields like the media and the arts," notes Lance Schachterle, associate dean of undergraduate studies and chairman of the Interdisciplinary Studies Division.

Currently, a committee of faculty members from the Humanities, Electrical and Computer Engineering, and Computer Science departments is just beginning the process of looking into the feasibility of major or double major programs that combine music and technology.

Notes William R. Grogan, dean emeritus of undergraduate studies, who is assisting the committee, "Music is becoming an amazingly sophisticated field. It not only involves electrical engineering, which plays a role in audio and electronic sound reproduction, but computer science, since so much of music is now reproduced and transmitted digitally.

"The average electrical engineer does not have much background in music, nor does the average musician have much background in computer and electronic technology," Grogan adds. "Someone conversant with both areas could have quite an interesting career."

At WPI, such a major or dual-major program would build on a great deal of existing student interest, notes Louis Curran. "It would be a natural for the Institute," he says. "So many students already have synthesizers or computers that reproduce music, and many more are highly into audio. And, our computer music courses are always oversubscribed."

"We have, through the humanities and arts program at WPI," Schachterle adds, "the opportunity to show that both sides—technical and humanistic—are creative, that both sides can be well-developed, and that a combination of those two can provide an increasing number of students with exciting career opportunities."

Restoring a Legend

As resident program manager for the Pentagon Renovation Program, Tony Leketa '69 is responsible for one of the largest construction projects ever undertaken by the U.S. Army Corps of Engineers.

By Ruth Trask

Fifty years after it rose from the site of a former military depot in Arlington, Va., in one of the most massive and ambitious construction projects undertaken in modern times, the Pentagon is getting a much needed overhaul. Among the most easily recognized buildings in the world and the hub of the nation's defense programs, the Pentagon has fallen on hard times in recent years.

After nearly five decades of neglect, the aging heating and refrigeration plant is no longer up to the task of heating and cooling the building's 6.5 million square feet of floor space. Its interior walls are riddled with holes made by roving utility carts. Even the building's massive reinforced concrete facade is cracking and spalling in places. The renovation program is being managed by the U.S. Army Corps of Engineers. It is one of the largest jobs ever undertaken by this, the largest construction organization in the world.

PHOTOS COURTESY OF U.S. ARMY CORPS OF ENGINEERS

Anthony Leketa on-site at the Pentagon.

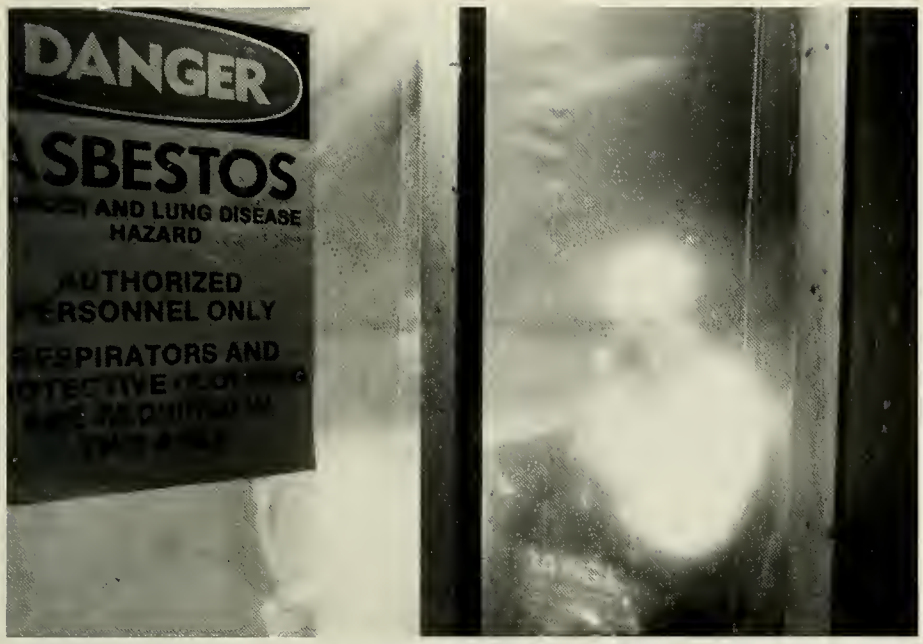
The resident program manager for the $1.4 billion project is Anthony F. Leketa '69, an engineer with the Army Corps of Engineers. Leketa is no stranger to huge construction projects. In the late 1980s, he headed the $1.3 billion Fort Drum Expansion Program in New York, which included the largest military construction contract awarded since World War II.

"Fort Drum was a civil engineer's dream," says Leketa, whose management of the mammoth project earned him the Wheeler Award, the highest honor given by the Society of American Military Engineers, and the Army's Meritorious Civilian Service Award. "Now I'm working on the Pentagon. That's pretty exciting stuff for a former Worcester boy who once played with a $1.50 Erector set."

Leketa describes the Pentagon project as his "second once-in-a-lifetime challenge." While supervising a staff of 165 on the construction of Fort Drum, he had the opportunity to build a city on 7,000 acres of virgin woodland. Like the Pentagon construction program (see related story, page 25), the Fort Drum effort was marked by a relatively short but intense period of design and construction. Just three years elapsed from the start of design work to the time soldiers moved in in 1987.

The army post, which can accommodate 10,000 soldiers and 25,000 civilians and family members, contains 35 miles of new roads, 20 barracks, 3,950 housing units, child development and youth activities centers, a fire station, a safety and law enforcement center, chapels, a heating plant, a bowling alley, a shopping mall and more than 100 other buildings.

"Building a shopping center in the middle of Washington, D.C., is an everyday occurrence," Leketa says. "But there was



A major challenge facing the engineers planning the Pentagon Renovation Program is the large quantity of asbestos used in the building's construction.

nothing like that at Ft. Drum. We started from scratch." As project director, Leketa was required to address concerns from citizens in adjacent Watertown, N.Y., whose population doubled following completion of the construction program.

He also monitored the potential environmental impact on Lake Ontario, which lies just 25 miles away, making changes as necessary to comply with environmental regulations. The proximity of the post to Canada mandated additional considerations in the environmental area, especially with respect to emissions from the facility's coal- and wood-burning heating plant.

The Fort Drum "new city" project gave Leketa the opportunity to build something major from the ground up. He says he felt a great sense of accomplishment when it was over. "I loved that job," he says. "It meant working a zillion hours, but it was one of the most exciting assignments I've ever had—until now. The Pentagon renovation project tops everything."

The renovation of the five-story Pentagon, the largest low-rise office building in the world, is providing Leketa an entirely different set of challenges. Consider the magnitude of the project: the Pentagon covers 34 acres, has three times the floor space of the Empire State Building, and is twice the size of the Chicago Merchandise Mart. The Capitol Building could easily fit into any one of its five wedge-shaped sections. It contains more than 17 miles of corridors and has nearly 8,000 windows. It supports an office population that fluctuates around 25,000.

It is a self-sustaining community. Besides its own heating and refrigeration plant, it has medical facilities, a shopping mall, dining and athletic facilities, a post office, a library, a police force, and easy access to the Metrorail and Metrobus systems.

Recognizing the building's continuing decline and the need to have an efficient, logically arranged administration building for the nation's armed forces, the government decided to renovate the Pentagon in the early 1980s. In 1988 the Department of Defense commissioned the firm of Howard Needles Tammen & Bergendoff to develop a renovation concept. The firm evaluated nine possible strategies, ranging from renovating the entire building all at once to breaking the project into 150 increments of 44,000 square feet each. Ultimately, it was decided to renovate the building in five approximately equal wedges, to be completed one wedge at a time. The basement will be renovated separately.

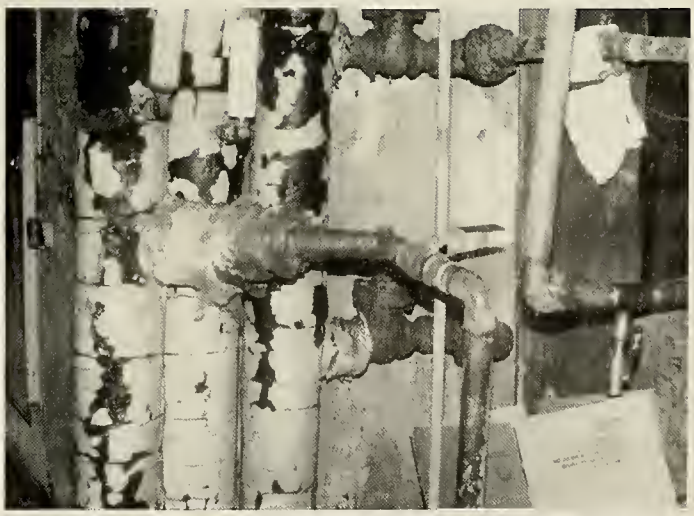
The major goals of the 10-year project are to provide safer working conditions (the building is woefully deficient in complying with current life safety codes), a modest increase in administrative space, better traffic flow inside and outside the building, better organizational alignment and security, enhanced communications, and a marked increase in energy efficiency.

In 1989 the Defense Department named the Corps of Engineers the design and construction agent for the program; the day-to-day activities are being managed by the Corps' Baltimore District, where Leketa is currently assigned. He says the major challenges the Corps faces revolve around the fact that the building has never had a major face-lift. In addition, there have been few changes to adapt the structure to current codes and to the changing nature—and electrical demands—of office work.

"These demands are overtaxing the original utility systems, resulting in increasingly frequent power outages," he says. "It is now common for 20 localized power outages to occur each day during the summer; this rises to 30 to 40 during the winter. The original heating and refrigeration plant is virtually out of service, as the boilers and chillers are inoperable. The distribution of heat and air-conditioning is equally unreliable, and steam and chilled water are furnished by packaged rental boilers and chillers."

In constructing the building's interior, the architects chose to use extensive amounts of asbestos-laden material. Asbestos is found in floor tiles, mechanical equipment insulation (including ductwork made of asbestos board to conserve metal for the war effort), the finish coat of all ceiling plaster, and some interior walls.

Under Leketa's direction, the entire building will be demolished to structure and completely rebuilt. In addition, all



A view of the Pentagon's deteriorating heating and cooling plant.

mechanical, electrical and communications systems will be replaced, a brand new HVAC system installed, all asbestos removed, all windows replaced, and the exterior given a face-lift.

But the renovation won't just overhaul the building's physical structure. Since it opened at the height of World War II, the Pentagon has become an increasingly complicated and congested warren of offices, corridors and stairwells. Related offices are now often located at distant corners of the building and traffic patterns can be confusing for those not familiar with them.

As part of the renovation, space assignments will be reorganized so tenants with similar functions will share the same or adjacent space. This should eliminate a great deal of corridor traffic, Leketa says. The second floor will become the primary level for horizontal circulation in the building; new passenger elevators (the building currently has no passenger elevator service) will introduce vertical circulation, with tenants being organized around their own vertical circulation systems. A corridor management plan will be developed to separate service and pedestrian traffic between office and service elevators.

The Pentagon project also includes some aesthetic changes and the construction of an extension to the building, parts of which are listed on the National Registry of Historic Places. The 500,000-square-foot extension, called the Pentagon Maintenance Facility, will be built at the Mall Entrance. It will house light industrial functions such as the maintenance shops, the Defense Protective Services, the three Pentagon medical clinics and the loading dock.

The basement/mezzanine level will be completely renovated, adding about 200,000 square feet of usable space. New two-story, secured access points will be built at the main entrances and atriums will be created at the five inside corners of the building.

"The building itself appears to be basically structurally sound," Leketa says. "But there is significant cracking of concrete at the inside light wells and along the interior drive, which will have to be repaired. Also, the athletic club and basement floor slabs show signs of settling."

Improvements will also be made to the area around the building, including extensive site work, parking lot resurfacing and bridge restoration. Vehicular traffic patterns, especially in the south parking lot, will be updated to meet the demands created by the presence of nearby Interstate 395 and the addition of Metrorail and Metrobus service.

The renovation will be accomplished in eight phases, Leketa says. Throughout the process, the Pentagon, which is the center of the nation's military capability, must remain operational. To that end, Leketa's team must find temporary accommodations—either inside the building or elsewhere—for occupants. Leketa is supervising all design and construction activities from a new modular office complex at the north end of the Pentagon's north parking lot. His staff, which currently numbers 30, will grow to about 70 before the project is done.

Leketa's office recently awarded the first major construction contracts: for a new $71 million heating and refrigeration plant and a $6 million classified waste incinerator upgrade at the existing heating plant. The heating and refrigeration plant will provide 240,000 pounds of steam per hour and 37,500 tons of chiller capacity for cooling. "Currently," he says, "we are overseeing design contracts for the Mall Terrace extension and the basement renovation. We are also involved in more than 100 planning and development studies."

Prior to heading the Pentagon and Fort Drum projects, Leketa served as area engineer with the Northeastern Area Office of the New York District Corps of Engineers located at Fort Devens in Ayer, Mass. At Devens he was responsible for administering more than $100 million in construction contracts for the U.S. government and supervising the activities of 50 engineers dispersed over nine field offices in the six New England states.

The projects he oversaw included a major rebuilding of Loring Air Force Base in Caribou, Maine, and the renovation of the Fargo Building (now known as the Barnes Building) in downtown Boston. The Barnes project was a total renovation of a 600,000-square-foot, nine-story structure.

A registered professional engineer in Massachusetts, Leketa didn't start out as a civil engineer. At WPI, he earned a bachelor's degree in chemical engineering and later earned a master's in civil engineering (water resources and sanitary engineering).

An active member of the Army Corps of Engineers for 10 years, he served as a captain on tours of duty in Korea and Germany. He graduated from the Army Command and General Staff College and is currently a lieutenant colonel in the Army Reserve in command of a military police battalion at Fort Eustis in Virginia. He was recently selected to attend the Industrial College of the Armed Forces at Fort McNair in Washington, D.C.

Leketa's memberships include Scabbard and Blade, Chi Epsilon (the civil engineering honor society), the American Society of Civil Engineers, the Society of American Military Engineers, the Reserve Officers Association and the U.S. Army Engineer Association. At one time he was a partner in his own business, Associated Building Inspectors. When he's not on-site at the Pentagon, he relaxes with photography, running, tennis and racquetball.

With one of the biggest construction projects in recent memory in full swing, there's little time for recreation. But that's no problem for Leketa, who says he thrives on the huge responsibilities his work for the Corps of Engineers brings him. "My idea of hell would be sitting at a desk doing design calculations," he says. "If I couldn't get out there and see what's going on, it would drive me crazy. The renovation of the Pentagon represents a monumental challenge, and I'm tremendously excited about being in the thick of it."

Leketa, far left, meets with some of the 30 staff members who currently report to him to review the myriad details of the complex renovation project.

Rome Wasn't Built in a Day, but the Pentagon Nearly Was

By Anthony F. Leketa '69

Conceived over the course of a weekend in July 1941 and approved by Congress a month later, the Pentagon, the world's largest low-rise office building, was built in just 16 months by construction teams working around the clock.

The Pentagon. Mere mention of the name conjures up images of staff officers holding classified documents under their arms, hurrying to the offices of high-ranking generals. And the appearance of national media personalities reporting from the Press Room enhanced the impression of the Pentagon's power and importance during the Persian Gulf War. After the White House and the Capitol Building, the Pentagon is probably the most important building in the U.S. and probably the most easily recognized.

When war broke out in 1939, tremendous demands were placed on the War Department, which was then housed in several dispersed, overcrowded locations in the Washington, D.C., area. Lt. Gen. Brehon B. Somervell, commanding general, services and supply, is credited with the idea of consolidating the mushrooming department in a single building. And so, in the summer of 1941, the Pentagon was conceived.

Somervell called Lt. Col. Hugh J. Casey and George E. Bergstrom, president of the American Institute of Architects, into his office on the evening of Thursday, July 17, 1941. He directed them to produce, by 9 o'clock Monday morning, the basic plan and architectural perspective for a four-story, air-conditioned building to house 40,000 people.

Somervell received his plans on-time; they called for a reinforced concrete structure of 5.1 million square feet. Most interior space would be open, and only senior officials would have private offices. Parking was provided for 10,000 cars. The building would solve wartime space problems for many government agencies competing for room in Washington, and it was estimated that War Department productivity would increase by 25 to 40 percent.

The first site selected was the Washington-Hoover Airport on the Virginia bank of the Potomac; it was immediately ruled out because it was in the Potomac's floodplain. The next site considered was Arlington Farms, a 6.7-acre plot adjacent to Arlington Cemetery. It was bounded by five roads, and when Bergstrom and Casey fitted their concept to the site, a building with five sides seemed best.

The concept didn't have universal support and there was considerable debate in Congress about the need and scope for such a building. Nevertheless, the project was authorized on Aug. 25, 1941. But before construction could begin, the location was changed again. President Roosevelt objected to the Arlington Farms site and directed that the new headquarters be built farther south in an area then used as a military depot. Somervell kept the design concept and directed that construction start immediately.

The most amazing statistic of the original project is the time it took to be built. A peak labor force of 13,000 workers took 16 months, working around the clock, from the date working drawings and specifications were started in September 1941 to completion in January 1943. That period included a late change to the plans that added a fifth floor and extended the construction schedule two months.

The chief of engineers at the time was Maj. Gen. Eugene Reybold, but the construction was completed under the direction of the deputy chief of construction, Col. Leslie R. Groves, who later headed the Manhattan Project. The contractor was a joint venture of John J. McShain of Philadelphia and Doyle and Russell and Wise Contracting Co., both of Richmond, Va. The chief architect/engineer was George Edwin Bergstrom, among whose accomplishments was the Hollywood Bowl in Los Angeles.

The Pentagon was designed for efficiency, not beauty. Roosevelt conditioned his approval of the project on a guarantee that no marble would be used in its design. The only significant ornament on the building's exterior is a commemorative cornerstone at the Mall Entrance—a limestone plaque listing the key participants in the building construction.

The architectural style used has been described as "starved classicism" and "government international." The Pentagon is a practical building. Its design and construction emphasized the conservation of critical war materials, particularly copper and steel. The low structure allowed reinforced concrete to be substituted for a steel frame; the mile-round perimeter wall is also made from reinforced concrete faced with Indiana limestone. It has been estimated that enough steel was saved in the construction of the Pentagon to build a battleship.

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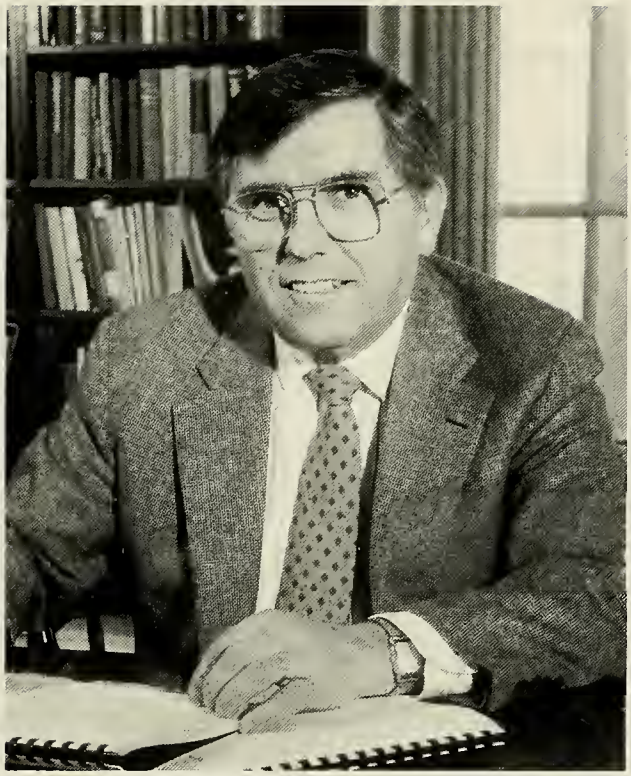
Investing the Future

In recent years, WPI has taken a long, hard look at how it manages one of its most vital resources. Out of that self-examination has come a comprehensive strategy for investing the endowment, a strategy that reflects not only the need for greater endowment growth as the Institute plies the uncertain financial seas of the decade ahead, but the critical role endowment earnings will play in WPI's ability to grow and change as higher education—and society itself—evolve.

By Diane Benison



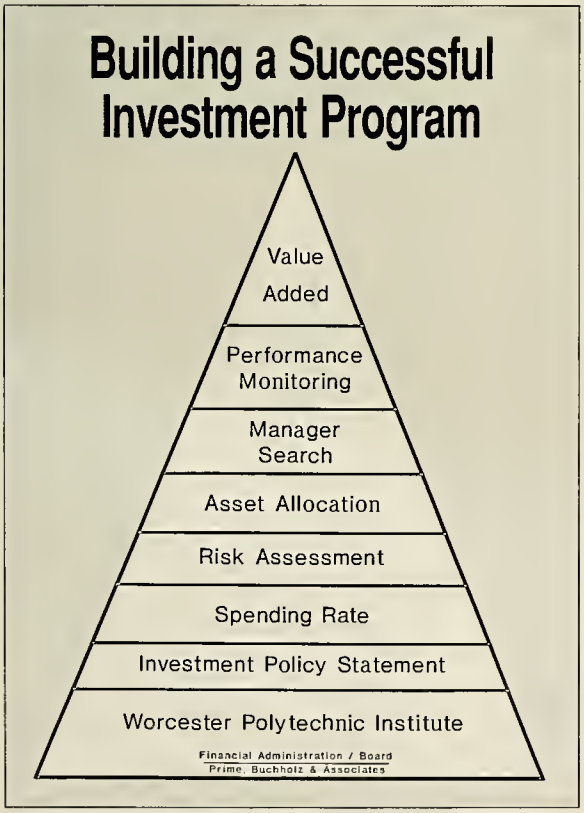
JANET WOODCOCK

WPI treasurer Robert W. Gailey drafted a formal investment policy with the objective of enhancing the return on WPI's endowment assets while protecting the endowment's purchasing power.

If they think about it at all, most people tend to envision an endowment as a large pool of money, passively invested. Until recently, that was largely true.

In its simplest form, an endowment is a permanent fund, the earnings from which are used to provide ongoing financial support to an institution. Unlike the reserve account a business might set up or the savings account an individual might establish, an endowment is not intended to be a cushion against bad times or a source of financial reserves. Rather, it is a permanent working asset that will continue to generate funds for current operations as long as the institution exists.

In higher education, endowment is usually made up of two components: true endowment and various funds functioning as endowment. True endowment consists of endowed funds that donors have designated for specific programs or purposes. The second component, sometimes called board-designated or quasi-endowment, consists of funds placed in the endowment—usually at the election of the board of trustees—to be invested and used as if they were part of the true endowment. About 40 percent of WPI's $118 million endowment is true endowment; the remainder is board-designated, according to Robert W. Gailey, treasurer and vice president for business affairs.



Because they have not been restricted by a donor, quasi-endowment funds can be withdrawn and spent at the discretion of the trustees. In practice, though, boards are usually unwilling to treat quasi-endowment as a savings account because of the value of having the predictable income these funds generate. As RPI president Roland W. Schmitt said in a recent talk at WPI, "Finances cannot make a university great, but their lack can most assuredly keep one from becoming great."

A predictable income stream from endowment is one of the four principal sources of revenue for most colleges and universities. The others are tuition, gifts and research funding. As many colleges struggle to rein in tuition increases, as a poor economy and changing national priorities put the squeeze on corporate and individual gifts, and as federal and state research funding becomes scarcer, the importance of predictable endowment earnings has never been greater.

As they are at most colleges, endowment earnings are added to the college's general fund to be spent on current programs and activities. At WPI, a large and growing portion of those operating funds is spent on student financial aid. During the fiscal year that ended June 30, 1992, for example, when about $4 million in endowment earnings were applied to the general operating funds, the Institute provided students with nearly $10 million in financial aid from its own funds.

"Clearly," notes WPI President Jon C. Strauss, "without those endowment earnings—including about $1.5 million derived directly from endowment funds restricted to finan-

cial aid—WPI would be hard-pressed to provide that level of financial assistance to its students—and far less able to compete for talented young men and women."

"I think institutions like WPI do very well to have endowment as part of their financial skeletons," notes former WPI treasurer Joaquim (Joe) S.S. Ribeiro '58, who is currently principal of Jefferson Financial in Jefferson, Mass. "A good solid endowment is part of your balance sheet. But its value lies not only in the fact that it generates funds; it also gives the institution a sense of steadfastness and strength. And it gives people who are dealing with the institution the feeling that it is here to stay."

The fiduciary responsibility for WPI's endowment has always rested with the Board of Trustees. During the Institute's early years, the board delegated that responsibility to various trustees or administrators. Often, the task of prudently managing the endowment funds fell to a single individual, generally the Institute's treasurer. That manner of handling endowments was neither uncommon nor unreasonable, for until recently the financial markets were simpler than they are today, with far fewer options for investing money.

At some point, as the board began to implement a committee system, oversight of the management of the endowment became an official function of the Budget and Finance Committee. In practice, however, it was still often a one- or two-person job.

That was how things were in 1964, when John E. Hossack '46 joined the board. Like his father, Archibald Hossack '12, John Hossack spent his entire career with American Appraisal Co., the international real estate and asset appraisal firm headquartered in Milwaukee. And like Archibald Hossack, who was a WPI trustee for more than 10 years, serving for much of that time on the Budget and Finance Committee, John would spend many years on the trustees' budget oversight committee.

When Hossack was named to the committee in 1966, most of the endowment funds were being managed by local banks. Believing that bringing more diversity to the endowment management team would result in greater security for the funds and a greater likelihood of endowment growth, he advocated moving some of the endowment funds out of Worcester and into the hands of other investment managers. His arguments were persuasive, and the board soon voted to do just that.

That decision marked the start of an era of great change for the management of WPI's endowment, although Hossack, who became chairman of the Budget and Finance Committee in 1971, says he couldn't have foreseen then how far-reaching that change would ultimately prove. For no one, Hossack notes, could have predicted the extent to which the world of investment would evolve, nor could they have foretold the financial crunch that would bring the management of college and university endowments to prominence just a few decades down the road.

A WPI trustee since 1964 and the first chairman of the board's Investment Committee, John E. Hossack '46 has long been an advocate of the need to protect the endowment principal from erosion by inflation.

From the beginning of his tenure on the Budget and Finance Committee, Hossack was a strong proponent for the need to protect the endowment's principal from erosion by inflation. "WPI should have a goal of earnings—plus inflation," he says, "and the inflation portion should be plowed back into endowment to preserve its purchasing power. If you don't do that, you're just gradually eating your cake."

At the recommendation of Hossack's committee, the Institute established a formal "spending rule," sometimes called the "spending rate." A spending rule defines exactly how much of the earnings from endowment may be used each year to meet current operating expenses. WPI's spending rule sets that amount at 5.5 percent of the average market value of the endowment—and its accumulated income and gains—for the previous two years.

For example, if the total endowment were valued at $100 million in one year and $110 million in the following year, its average market value for those two years would be $105 million. According to the spending rule, in the third year the Institute could remove 5.5 percent of that value, or $5,775,000, from the endowment and add it to the income side of its restricted and unrestricted budgets. The spending rule allows WPI to make reasonable predictions about how much money will be available from the endowment each year, Gailey says, making the budgeting process more orderly.

WPI's 5.5 percent spending rate is slightly higher than the average of the rates adhered to by the country's more

From a $100,000 Seed, A $118 Million Oak Has Grown

It may not seem like a great deal of money today, but when John Boynton turned over his founding gift of $100,000 to the trustees of the new Worcester County Free Institute of Industrial Science in 1865, it was nearly everything he had amassed during a long and successful career as an entrepreneur and bank president.

In accepting Boynton's fortune, the trustees took on a lofty responsibility, for that gift would become the seed for the Institute's endowment. Through prudent investment and the addition of many more gifts, that $100,000 seed has become a mighty $118 million oak.

That growth didn't happen overnight, of course. As the graph on this page shows, the majority of the ascent has occurred only within the last few decades. In fact, as recently as 1964 the fund stood at about $18 million, one-tenth of its current value. Four major fund-raising campaigns since then—the *Centennial Fund* (1964 to 1967), the *Plan to Restore the Balance* (1972 to 1977), the *Capital Program* (1980 to 1983) and the *Campaign for Excellence* (1985 to 1990)—have helped provide momentum.

During the 1980s endowment growth was aided by a robust economy that yielded high returns on all types of investments. That positive environment plus the great success of the *Campaign for Excellence*, which exceeded its $52.5 million goal by 21 percent, enabled the endowment to surge from $38 million as the decade opened to more than $100 million as it closed.

The success of recent years is in sharp contrast to the endowment's first few decades. In those early years, persistent debt and frequent deficits plagued the college. A treasurer's report from the early 1880s notes a $15,100 shortage in the endowed funds due to heavy drafts made upon them.

Generous gifts from Ichabod Washburn, Stephen Salisbury, David Whitcomb and George Hoar, along with an appropriation from the state, helped the endowment grow to just over $379,000 by the end of 1882. The following year the Institute launched a $110,000 campaign to build the fund; in the end, half that much was raised, largely through a few major gifts.

For many years the Institute depended on regular state grants to fund its operations and enlarge its endowment. But in 1917 the state legislature passed the "Anti-Aid Amendment," which called for the end to general state grants to private educational institutions. By the time these allocations ended in 1921, the Institute had benefited from more than $800,000 in state funds.

To replace the state money, WPI needed to increase its $1.1 million endowment by $1 million. But that would just maintain the status quo; to pull itself out of a period of stagnation and prepare for the future, the college would need an additional $1 million.

A fund-raising campaign was launched, which drew support from nearly 90 percent of alumni. A major incentive was a challenge grant of $350,000 from the General Education Fund, created by John D. Rockefeller with the intention of increasing teachers' salaries across the country. To receive the funds, the college had to raise $650,000—a goal it ultimately achieved.

About $375,000 was accrued via a novel fund-raising vehicle called the industrial sustaining scholarship. Through this program, a company, with a gift of $10,000, could create a scholarship that gave it the right to name an employee or the child of an employee on a yearly basis to attend WPI tuition free.

In all, more than $1.5 million was raised in the brief campaign. While well short of the $2 million goal, the drive got the Institute out of trouble, bridged the gap created by the loss of the state grants, and brought the value of the endowment to more than $2 million by 1922.

But more important, the campaign highlighted the vital importance of the endowment to the ongoing success and continuing growth of the Institute. It also set a new standard for financial support for alumni and friends of the half-century-old institution at the same time it laid the groundwork for the next 75 years and the next $116 million of endowment growth.

—Michael Dorsey

WPI's Endowment: 1865 to 1992 *(in millions)*

Methods for reporting the value of the WPI endowment have varied over the years. The values used in this graph for the years 1953 to 1992 are market values. The figures for the years 1936 to 1952 are book values. The values for the years prior to 1936 were taken from a graph in Herbert Taylor's Seventy Years of the Worcester Polytechnic Institute *and are most likely book values.*

JANET WOODCOCK

William F. McCarron, left, and James R. Buchholz of Prime, Buchholz & Associates Inc., which serves the Institute as an independent endowment management consultant.

than 3,000 institutions of higher education. Like other colleges and university divisions that specialize in science and engineering, WPI has higher operating expenses than most liberal arts colleges due to the high cost of buying and maintaining the state-of-the-art laboratory and computer equipment needed to teach students and conduct research in technical disciplines.

Until recently, the spending rule was applied only to board-designated endowment. But in 1992 the administration recommended—and the trustees approved—applying the rule also to the true endowment, where it can legally do so. When donors stipulate that all income from their gifts be spent for specified purposes, the trustees have no choice but to comply. Only about 2 percent of the restricted endowment is covered by such stipulations, Gailey says. Over time, he notes, inflation eats away at those funds, diminishing their purchasing power. Because it is based on the need to account first for inflation, the spending rule will now help preserve the real value of the remainder of the true endowment over time.

Formalizing the spending rule and diversifying the management of the endowment were important first steps toward a comprehensive strategy for growing the endowment in a sound and secure manner. The stage for the next move down that path was set in the late 1970s and early 1980s. As the endowment enjoyed a steady rate of growth, consideration was given to the idea of separating its management from the other duties of the Budget and Finance Committee. With the increasing size of the endowment (see graph, page 29) and the growing complexity of the field of financial management, it was becoming clear that the endowment required more time, attention and input—and from a wider circle of people.

For while the creation of the Budget and Finance Committee had, in theory, spread the responsibility for supervising the endowment management over a reasonably large team, in reality that oversight responsibility still generally defaulted to just two people: Hossack and David E. Lloyd (then the Institute's treasurer), the two men who had the greatest interest in—and accountability for—the endowment.

By the mid-1980s, when the *Campaign for Excellence*, the Institute's most recent fund-raising drive, was launched, the idea of creating a separate entity to oversee the investment of endowment funds had earned the general support of the board, of the Institute's new president, Jon C. Strauss, and of Ribeiro, its newly installed treasurer and vice president for business affairs.

Strauss had been a chief financial officer at the University of Pennsylvania and at the University of Southern California at Los Angeles. When he came to WPI in 1985 he had a deep understanding of the role endowment plays in the long-term welfare of a college or university. Ribeiro, who had worked with endowment-like funds at several nonprofit organizations in Worcester, also held strong views on the importance of managing the investment process. While Hossack, Strauss and Ribeiro were not always in accord concerning technical aspects of investing, they shared a passionate belief in the importance of protecting the endowment from erosion by inflation.

In 1986 the Board of Trustees created the Investment Committee—separate from Budget and Finance—to have fiduciary oversight over the management of endowment funds. Hossack served as its chairman until September 1992, when he turned the reins over to F. William Marshall Jr. and assumed the post of vice chairman.

As the *Campaign for Excellence* concluded on Nov. 11, 1990, adding about $15.4 million of its $63.7 million total to the endowment, Gailey, in consultation with the Investment Committee and Strauss, was deeply engrossed in the

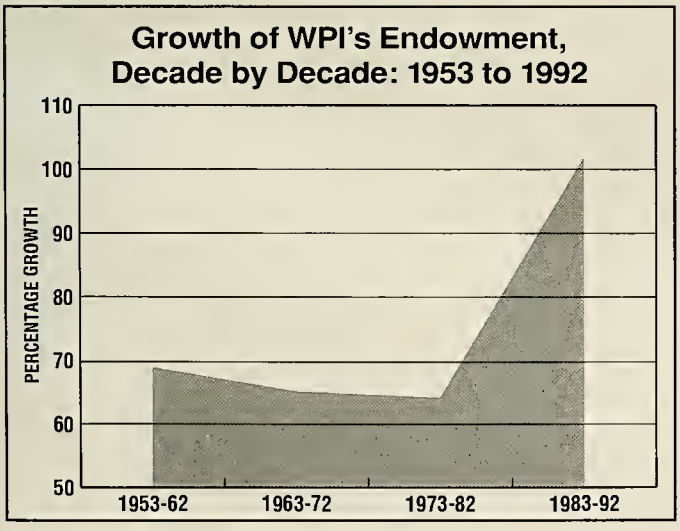
work of writing a policy that established clear investment objectives and goals for WPI.

In separate interviews, Hossack, Strauss, Ribeiro and Gailey expressed similar sentiments about endowment management, sentiments that are reflected in the policy Gailey drafted. All noted that preserving the endowment's purchasing power is essential. But they also stressed the need to take more risks to produce a better return on endowment investments.

Strauss, who calls a strategy that encompasses both objectives "prudently aggressive," believes that the significant growth of the endowment during the 1980s (see graph below) may have created a false sense of security. "If you see that we've got a $118 million endowment today and compare it to the $50 million endowment we had just 10 years ago it looks pretty dramatic," he says. "But when you look at it in the context of an operation of our size, with a $75 million operating budget and a $150 million physical plant, it doesn't seem all that large." It is also important, Strauss notes, to compare WPI's endowment to those of other high-quality colleges and universities (see table).

A fundamental issue that faced Gailey and the Investment Committee as the policy was being drafted was how much of the endowment should be invested in three broad classes of assets: equities (stocks), fixed-income instruments (bonds and U.S. treasuries, for example), and specialized investments (such as real estate and venture capital). The resulting investment equation, they knew, would have to meet Strauss' prudently aggressive test.

The members of the Investment Committee decided the Institute would need a disinterested advisor if it were to effectively monitor and hone this and other investment practices and strategies. They realized that for the most part, the outside managers then employed to manage endowment assets could not act in that capacity, since some were also responsible for investing part of the WPI portfolio, while others were hired solely to provide comparative reports on the performance of the various managers.



Endowment Growth
1975 to 1990
for WPI and 12 Other Private Colleges and Universities

	Market Value of Endowment (in millions)			
	1975	1980	1985	1990
Liberal Arts Colleges				
Bowdoin	39.1	49.9	94.8	151.7
Bucknell	28.0	37.5	62.2	98.2
Colgate	23.8	34.5	69.8	136.0
Middlebury	31.0	62.0	128.4	227.8
Mt. Holyoke	41.4	58.2	96.8	180.0
Trinity	29.7	43.0	74.1	137.4
Engineering and Science Institutions				
Caltech	142.1	198.4	275.9	467.0
Carnegie-Mellon	103.4	119.2	193.5	299.2
Lehigh	53.2	61.9	130.1	260.4
Rensselaer	78.2	93.6	144.6	230.2
Rochester Institute of Technology	63.1	59.5	91.2	165.8
Rice	187.1	342.1	609.3	1,068.6
WPI	**25.2**	**38.1**	**64.9**	**98.3**

Source: Council for Financial Aid to Education

One exception was the firm of Prime, Buchholz & Associates Inc. of Portsmouth, N.H. Prime, Buchholz was then providing quarterly reports to the Institute on the performance of its endowment investments. Because of the company's expertise and experience with college endowments, WPI in the spring of 1991 chose the firm to act as its independent endowment management consultant.

With a staff of six professionals, Prime, Buchholz is a small, highly focused specialist. Now in its fifth year, the firm is a consultant to 48 nonprofit institutions that collectively hold more than $3 billion in assets; 60 percent of the firm's revenue is derived from its work for colleges and universities. Founders Jon L. Prime and James R. Buchholz are former university chief financial officers; each, in fact, once served as the CFO at Rochester Institute of Technology. Prime was also vice president of Swarthmore College and St. Louis University, while Buchholz is former vice chancellor of Washington University in St. Louis and vice president of the University of Missouri System.

"There's been an evolution in the history of the way boards have managed endowments," Buchholz says. "Many years ago they were primarily focused on the maintenance of nominal value. But as inflation started ravaging institutions in the '60s, '70s and '80s, they became more and more interested in the maintenance of the real dollar values."

Buchholz says there wasn't much known about the performance of endowment funds in higher education until the mid-1980s when the first substantive report on the subject, *Improving Endowment Management*, was published by the Association of Governing Boards. Jon Prime was a principal contributor to that study, which measured the endowment performance, over five years, of 23 sample institutions and

then compared those figures with national averages for colleges and universities.

The study found considerable variation in performance among the institutions studied. When the authors dug deeper to find the causes of that variation, they discovered that the better-performing endowments were "more disciplined, more systematic—they worked harder at it," Buchholz says. The authors listed six major characteristics that distinguished the more successful funds. At those institutions, the fiduciaries had

- articulated what they were trying to accomplish and written down their objectives.
- set a spending rate that took into account the need to maintain the purchasing power of the fund.
- decided how much volatility they were comfortable with.
- looked at historic rates of return for different classes of assets and decided how much of their funds would be allocated to each.
- chosen managers only after they'd decided on asset allocation, and selected those managers based on excellence, not on historic affiliation or proximity to the institution.
- and measured progress toward their own objectives and compared their performance to that of other institutions doing similar things with their investments.

NEIL NORUM

An endowment says an institution "is here to stay," says former WPI treasurer Joaquim Ribeiro '58.

Providing a Framework for Investing

Editor's Note: *On May 15, 1991, the Board of Trustees approved a formal policy to guide the Institute in investing the assets that collectively make up the endowment. The board had previously passed a separate policy providing guidance on considering social concerns in making investments. Both policies are reprinted here in their entirety.*

Investment Policy

By resolution, the Board of Trustees of Worcester Polytechnic Institute, on recommendation of the Investment Committee, has adopted the following investment objectives for the Institute's endowment:

Investment Objective

Recognizing the significance of the Institute's endowment in providing a critical margin of financial support for its long-term academic programs and general operation, the Board of Trustees assigns a high priority to the productive management of endowment assets. As a minimum, it is the objective of the Institute to preserve the real principal value of its endowment. It is hoped that prudent investment management and continuing development efforts will enhance growth beyond this minimum objective.

The endowment is to be managed for total return, with a stated percentage of total market value used annually towards the Institute's budget. Such a policy will allow for the greatest investment flexibility, and for growth over the long term of the endowment's contribution to the Institute's operations.

Asset Allocation and Spending Policy

As the maintenance of the endowment value in both real and nominal terms is best accomplished by a significant equity allocation in the overall portfolio, it is expected that the long-term asset allocation of the endowment will be approximately 60 percent equity, 35 percent fixed-income, and 5 percent specialized investments. The Investment Committee may authorize asset allocation as deemed prudent. It is recognized, however, that variation from the long-term policy reducing equity exposure can be detrimental to the university's long-term objectives of spending and endowment growth.

The spending level from endowment assets is critical to the long-term maintenance of real endowment value. Therefore, the Institute adopted a policy of spending 5.5 percent of the average unit market value at close (June 30) for the previous two fiscal years. Such a policy allows for reasonable predictability of income available for current operations; allows for a gradual, steady growth of the endowment's support of the Institute's operation; and minimizes the probability of invading endowment principal over the long term.

As a general objective, the Investment Committee expects this spending rule to be funded by no less than 85 percent from earnings. Therefore, the sale of securities will not be necessary for more than 15 percent of the spending rule.

JANET WOODCOCK

Investment Committee chair William F. Marshall is helping chart a course for the endowment's future.

That was precisely the kind of methodical approach Gailey had outlined in the Institute's new policy statement (see box below). The statement was adopted by the trustees in May 1991, shortly before Prime, Buchholz came on board as an independent consultant. Since then, the firm, along with the Investment Committee and the administration, has been working to implement the policy.

Over the long term, the policy calls for the allocation of 60 percent of the endowment assets in equities, 35 percent in fixed-income vehicles and 5 percent in specialized investments. The Investment Committee has been working to realign existing endowment investments to meet those goals. At the end of 1992, the endowment was about 54 percent invested in the equity sector, 40 percent in the fixed-income sector and 6 percent in specialized investments.

Each broad asset class can be further divided into a number of investment categories, all of which have associated risks and potential for return. "There's no single formula for spreading assets among different classes—one guaranteed to eliminate risk and produce high returns," Gailey says. "But like any investor, WPI, by understanding its own tolerance for risk, applying judgment and paying attention to historic performance trends, can make informed decisions."

Investment Management Evaluation

The Investment Committee is authorized to engage investment managers for the direct management of the Institute's endowment assets. By such action, the board expects to acquire expertise in investment management, which will benefit the Institute's long-term endowment growth. Secondarily, such delegation will provide for continuity in endowment management despite periodic personnel changes in board or Investment Committee composition, which will enable emphasis upon long-term objectives rather than short-term or ad-hoc decisions.

The investment managers will have discretion with regard to individual asset selection, although portfolio variability of return should be minimized through prudent diversification, both among individual assets and by asset class. The Investment Committee will review the investment manager's time-weighted returns vs. stock and investment style. Over a typical market cycle of three to five years, the investment manager is expected to outperform the broad market indices (i.e., S&P 500, Shearson Lehman Government/Corporate Bond Index, etc.) and exceed the median of comparable investment universes. Investment performance data will be provided to the Investment Committee through quarterly reports and meetings with the investment manager as deemed necessary.

Policy on Investments and Social Concerns

The investment of institutional funds to reflect social, moral or political interests has become an issue of widespread concern throughout the United States. Universities, in particular, have struggled with the question of what is appropriate in this regard while still recognizing their basic long-term responsibilities as educational institutions. Answers are not easy; the whole subject is complex and highly controversial. Summarized below is a statement of policy on this issue:

1. Worcester Polytechnic Institute, through its Board of Trustees, has fiduciary responsibility for the assets of the Institute and the investment of Institute funds. It has been, and remains, policy that this fiduciary responsibility is best satisfied by investing funds to maximize their total return and then employing this return to promote the primary purposes of the Institute. This policy recognizes the Institute's basic responsibility to its primary functions of teaching and research; it also respects the special fiduciary and ethical responsibility of the Board of Trustees for prudent investment of Institute funds for the educational purposes of the institution.

2. The Institute, as an investor and shareholder, supports affirmative action, equal opportunity and similar policies reflecting societal values. The Institute recognizes that, as an institution in society devoted to the search for and teaching of truth, it bears a responsibility in its investments to attempt to influence corporations engaged in practices contrary to the self-evident truths of individual human liberty and/or the good of mankind.

3. Ownership of investments and action on shareholder resolutions will be considered case by case by the President's Advisory Committee on Investments and Social Responsibilities to encourage corporate responsibility to employees, customers and society in general. The recommendation of the advisory committee will be transmitted to the trustee Budget and Finance Committee for review and possible action.

In 1992 the Investment Committee focused a good deal of its energies on the equity category, studying different models for selecting the best mix of stock classifications for WPI. One characteristic they chose for sorting out potential stocks is called "market cap," or the dollar value (capitalization) of each stock. The market cap is calculated by multiplying the number of outstanding shares by the current market price of a single share.

Large-cap stocks—those issued by big companies—tend to pay regular dividends and exhibit less volatility in price. Small-cap stocks, issued by smaller "growth companies," offer investors the greatest potential for price appreciation, but tend to plow their profits back into the business rather than paying dividends. For investors who wish to shield their money from the ups and downs of the U.S. economy—and benefit from growth in other countries—international stocks offer a good alternative.

Next to the students and the faculty, the endowment is the college's most important asset because it provides for today and ensures that there will be a tomorrow.

With those categories in mind, the committee, under chairman Marshall's direction, began a review of current fund managers and a search for new managers with specialized skills in each asset class. "Historically, the cocktail wisdom among fiduciaries was that manager selection was where 90 percent of the value was added," Buchholz says. "But the research now is rather conclusive that the majority of the return is driven by asset allocation. Of course, you have to be properly represented by investment managers capable of making the best possible day-to-day buy-and-sell decisions, but asset allocation is going to determine the outcome.

"The highest and best service a board can give an institution is making policy decisions—about what they're trying to accomplish and which assets are going to do that for them," Buchholz adds. "So, in a way, this kind of discipline, which colleges have increasingly been following, enhances the board's role and its effectiveness by getting the board members focused on policy."

Buchholz says his firm believes that any investor's best opportunity for long-term capital appreciation lies in having a substantial portion of its assets invested in diversified stocks. "Years ago diversification meant that rather than having 10 equities in the account, you had maybe 20, 30 or 40, and that instead of 10 bonds, you had maybe 20 or 30. Now we're talking about multiple asset classes that move across time at different tempos, and about having multiple economies represented in a portfolio."

Two decades ago, the U.S. economy represented about two-thirds of the world's capitalization; now it's one-third, he says. That change reflects the growth in other economies around the world, rather than the shrinking of the U.S. economy. Because of that shift, American investors are no longer insulated, as they once might have been—or thought they were—from the impacts of world events, a strong argument for "enhancing our concept of diversification," Buchholz says.

"With diversification, you're seeking to put dissimilar ingredients into an overall structure, so that when volatility strikes one asset class, it won't necessarily hit the others. You don't want asset classes moving in the same direction at once. If one is heading south, you want to have another one headed north."

Investment Committee chairman Marshall, who has been a bank president and a chief executive officer, says he shares Buchholz's views on the importance of sound policy and discipline. "Next to the students and the faculty," he says, "the endowment is the college's most important asset because it provides for today and ensures that there will be a tomorrow. People and organizations that have contributed their money to WPI have a right to know that it's going to be managed wisely and carefully."

The product of that wise and careful investing should be a "performance that is considerably superior to the major indexes," Marshall says. [WPI uses the Standard & Poor's 500 Index to measure the performance of its equity managers and the Lehman Brothers' Government Corporate Intermediate Bond Index as a yardstick for its fixed-income managers.] "I am purposely setting a high standard of performance. And I know the committee is excited about the prospect of what that standard can mean for WPI."

Marshall has scheduled six meetings in 1993 for the Investment Committee, though the group may well try to squeeze in a few more, he notes. Since each meeting runs about three hours, that represents a major commitment of time and energy for trustees who sit on the committee, especially those who must travel to Worcester from some distance. It also represents a financial commitment, since WPI does not reimburse its trustees for their time and travel expenses.

Marshall, an alumnus of Washington University who became involved with WPI when he was president and chief executive officer of Shawmut Worcester County Bank, says, "I believe strongly that education is our future. So this is an opportunity for me to make a contribution by helping an outstanding educational institution."

That's a common sentiment among the trustees with which he works, Buchholz says. "The intent of these boards is to do good—to add value," he notes. "What has become evident in the last 15 or 20 years is that those that are successful in the area of investments rely on something more than just the intent to do good. It's increasingly apparent that there's a discipline they can follow that will enhance the probability of long-term success. That's the track WPI is on."

A former newspaper editor, Diane Benison has written several articles for the Journal. *Her most recent stories explored the world of total quality management.*

The Endowment: Some Cold, Hard Facts

While it is gratifying to see the rapid growth of the WPI endowment—particularly in the past two decades—and to have played a role in that success during the most recent decade, there are several points I'd encourage readers of this magazine to keep in mind:

First: It's dangerous to measure one's progress against oneself. For example, our $118 million endowment, compared solely to its value in times past, might suggest that WPI is rich. But it is essential that we index that value against the endowments of peer institutions with whom we compete for students (see table).

Prospective students—and their parents—have become considerably more discerning over the years. There was a time when most colleges, including WPI, attracted students from within a relatively small radius of their campuses. Transportation was a more important limiting criterion than creature comforts (read campus center, athletic/exercise facilities, modern residence halls, and so on).

Today, what most people educated in that era would call "frills" figure more prominently in the attractiveness equation. And for all but a relative handful of students, WPI is, in fact, a "home away from home." (Something on the order of 5 percent of our students commute these days.) Building and operating such facilities places a growing burden on our operating budget and depends mightily on income earned through endowment—especially unrestricted endowment.

Second: It is common knowledge that historically, most engineering and science students have come from families with modest financial resources. In generations past, this often meant children of industrial workers—skilled and unskilled. More often than not, many of those parents had little or no college education.

While the level of formal education possessed by our WPI parents is far greater today than it was a generation ago (virtually all are college educated; nearly a fifth of WPI's current freshmen have parents who are school teachers), their relative financial position is unchanged. What all this translates into is that today's students must acquire increasing levels of "outside" financial support if they are to come here—or to an institution like WPI.

Indeed, virtually all private engineering and science institutions (Cooper Union and Rice University are notable exceptions, with both offering "free" or substantially reduced tuition due to the scale of their endowments) find that about seven out of every 10 of their students require aid—and lots of it! To put this issue in a context we can all understand, it costs WPI on the order of $10 million in financial aid to support its current undergraduate population.

If that cost were to be met strictly with earned endowment income (while still protecting the endowment principle from erosion by inflation), we would need an endowment on the order of $150 million right now. But that, of course, would also mean that anything else we did—building or substantially modifying facilities, starting new programs, enhancing maintenance allocations (much needed)—would have to come from on-going, pervasive fund raising. So, unless there is a marked change in the mix of high-need to no- or little-need candidates seeking a science and engineering education and who could be attracted to WPI, our resource base is going to be pressed to more than its limit.

Third: The maintenance of currency in science and engineering programs is a very expensive business. And while the same can be said for medical education, a willingness to pay for a high-quality private undergraduate education is invariably balanced against the debt one must acquire to obtain it and one's ability to pay that debt back with undue pain. It is clear that the realized (or perceived) material gains from careers in science and technology do not match those of careers in medicine.

The way we go about the business of educating scientists and engineers must be examined with an eye to cost containment. Like the overwhelming majority of our nation's hospitals, too many technical colleges and engineering and science colleges within universities are headed for financial ruin. We must apply far more ingenuity to tackling this issue than has been demonstrated in the last 20 years.

How we deliver our science and engineering programs must become as important an exercise as fund raising for them has been these past several years. The question is how to do it in a way that will leave these programs as the world's pacesetters—a position they've enjoyed for four decades.

Believe me—WPI has a long way to go before it can claim to be "rich."

—Donald F. Berth '57

Berth is vice president for university relations.

The WPI Endowment

A Comparison to Representative, Principally Science and Technology Institutions

	Endowment (in millions)	Total Enrollment	Endowment Per Student (in thousands)
Caltech	546	1,861	293
Carnegie-Mellon	313	7,261	43
Harvey Mudd	77	578	133
Lehigh	279	6,732	41
MIT	1,442	9,628	150
RPI	237	6,614	36
Rice	1,140	4,239	269
Stevens	47	3,114	15
WPI	**107**	**3,902**	**27**

Source: *Voluntary Support for Higher Education 1991*, Council for Aid to Education

The Rewards are Great— and Immediate— for Town Manager Norton Bonaparte

As town manager of Glenarden, Md., Norton Bonaparte tries to take the politics out of local government and see that the promises of elected officials are kept.

I like the idea of being able to make things happen for the public good," says Norton N. Bonaparte Jr. '75, town manager in Glenarden, Md., who says he discovered his passion for public administration while a civil engineering student at WPI. "My studies were focused on urban planning," he says. "But I soon discovered it was the urban environment—not planning—that piqued my interest."

Deciding to follow a career in public administration, Bonaparte earned his M.P.A. at the Cornell University School of Business. Early on he worked in Washington, D.C., on an internship at the International City Management Association. For four years he was an administrative assistant in the office of the city manager in Grand Rapids, Mich. And in 1988 he was named town manager in Glenarden. He says it was the right move. "Every morning when I wake up, I can hardly wait to get to the office."

Bonaparte says it is the duty of a town manager to make sure politicians' promises are kept. He says the council-manager form of government evolved in the early part of the 20th century in response to widespread corruption at the local government level. Today, he adds, city or town managers are seen as people who can take the politics out of the management of government.

"When you look at what gets a person elected," he says, "it's everything from giving good speeches to kissing babies to having a firm handshake. But those things have nothing to do with running a government."

In Glenarden, as in many towns and cities, the government is set up similar to a business, Bonaparte notes. In a business, the stockholders elect a board of directors which, in turn, appoints a president to run the company. In government, the elected officials set policy and establish an agenda; they then hire someone to manage the day-to-day operations of the government.

As town manager, Bonaparte says he is the chief administrator of the government. Most government departments, including the police and the public works department, report to him, and it is his responsibility to prepare a budget for the council's approval and then to implement that budget through his administration of the various departments. In essence, he add, he is the practical arm of local government, and Bonaparte says he thrives on being the muscle, helping to turn political rhetoric into practical reality.

Bonaparte starts flexing his muscles daily at 8 a.m., a half hour before the town offices open. Always on a tight schedule, he meets frequently with city and business leaders and citizens' groups to address their concerns, and attends meetings aimed at facilitating action within the community by combining the efforts of businesses, schools and neighborhood groups.

Bonaparte, shown here at a town meeting with Glenarden Police Chief M.A. Lewis, left, and Mayor Marvin Wilson, says he enjoys the opportunity his job affords him to make a real difference at the local level.

"At WPI," Bonaparte says, "I was chief justice of the Campus Hearing Board. That was a valuable experience, because it taught me to listen to and take into consideration the various sides of each case. That's a lesson I use all the time in my job today."

Part of his job involves overseeing the operation of 10 town departments that are responsible for everything from filling potholes to supervising major renovations in community buildings to maintaining town equipment. While he spends most of his time helping his department heads solve problems and set goals, he also takes responsibility for seeing that the local population is served as efficiently as possible.

"I note trends in population and try to make certain we have enough resources for the young and the elderly, as well as other groups," he says. "Finding the best ways to adjust and anticipating changes in demographics and social trends are important concerns for a town manager."

Because much of his time is spent speaking and writing, Bonaparte says the most important skills a town manager can have are the ability to get along with people and to communicate well through the spoken and the written word. An understanding of mathematics is also useful for deciphering computer data, and a knowledge of politics can be helpful, although the post, itself, he notes, is technically nonpolitical.

Bonaparte says he likes to believe what he does each day makes a difference. The advantage of working at the local level, he notes, is that results can be seen right away. If the streets get plowed, a town manager is a hero. If they don't, he or she must have a thick skin, because the phone will ring off the hook. "Unfortunately," he says, "people may not tell you you're doing a good job, but they'll let you know right off the bat if they think you aren't."

Although his decisions may, on occasion, invite criticism, Bonaparte enjoys working in local government because it is the closest a public servant can get to the people. "It's my goal to make things better," he says. "I've worked on the state and federal levels and the local level is the most immediately rewarding."

Bonaparte unabashedly infects his staff with his enthusiasm for professionalism. "I tell them our role is to serve, but not as servants," he says. "I explain that while it is said residents pay our salaries, I prefer to focus on the fact that they pay us to perform services. Our residents are our customers, and they want things to work properly."

Before deciding to accept the town manager's post, Bonaparte drove around Glenarden on weekends assessing the residents' attitudes about their town. "I could tell people took great pride in the area by the way they kept up their yards and houses. It made me want to become a part of it," he says.

Glenarden, once strictly residential, now has several commercial areas. "We stand for quality of service to the residents, no matter how the character of the town changes," Bonaparte says. "Glenarden is small, but has the same problems as larger municipalities because it is part of the Washington metropolitan area. So far, the town has met change well. I take great pride in that."

—Ruth Trask

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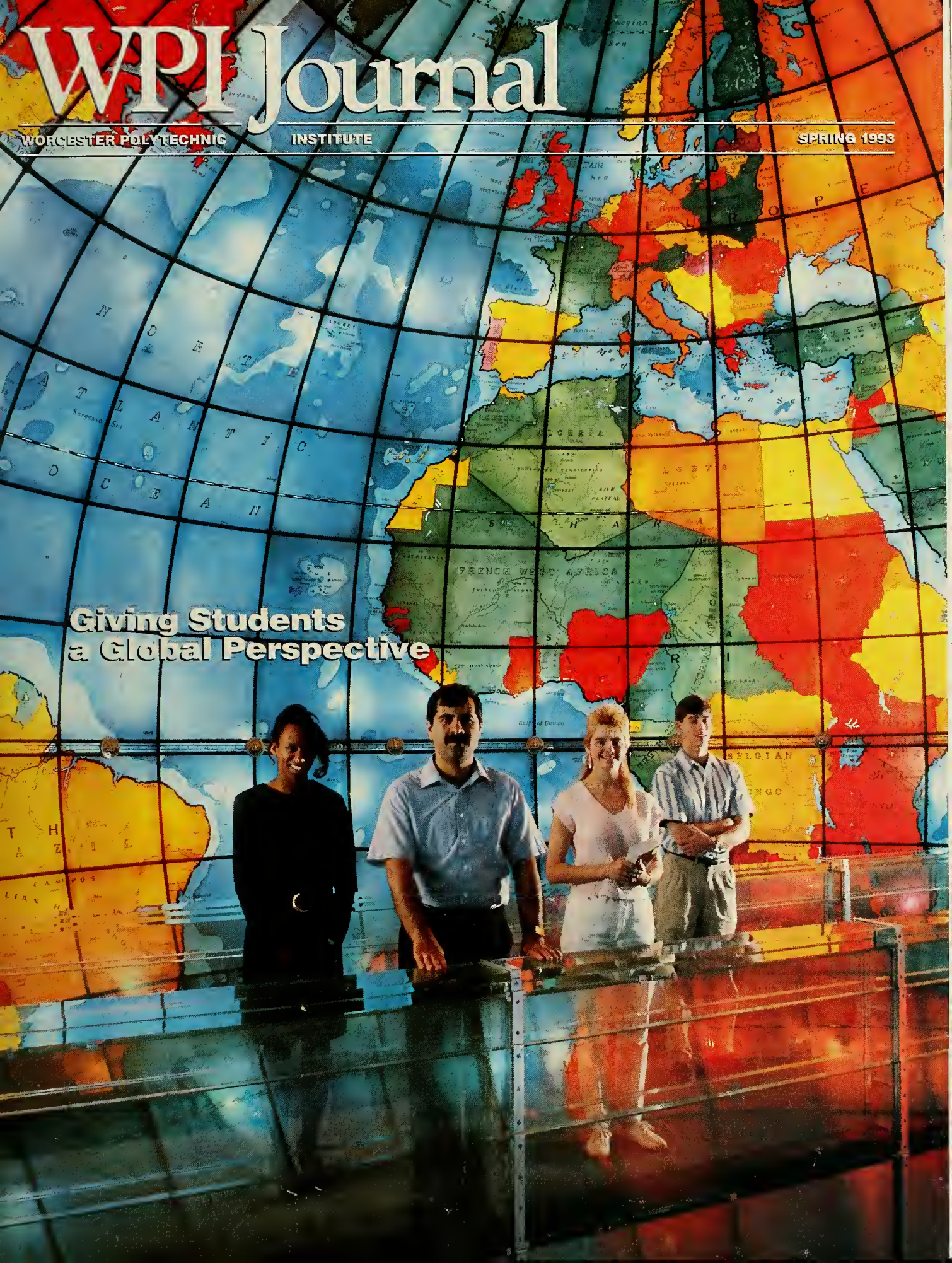
Giving Students a Global Perspective



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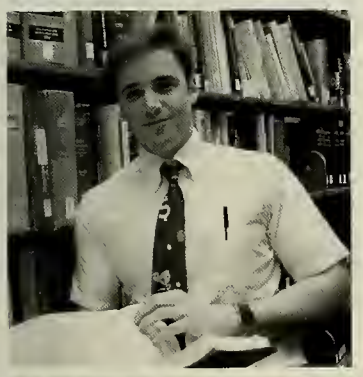

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Front Cover: Global Program Officer Hossein Hakim, second from left, with, from left, Naomi E. Carnegie '93, Jennifer L. Greenhalgh '94 and Michael A. Kaliski '93. Carnegie completed an Interactive Qualifying Project in San Juan, Puerto Rico; Greenhalgh did an IQP in Bangkok; Kaliski did his IQP in Venice. The photo was taken inside the Mapparium, a 30-foot stained glass globe at the Boston headquarters of the Christian Science Publishing Society. The globe was completed in 1935 and shows the world as it looked then. Story on page 5. Photo by Janet Woodcock. **Opposite:** Pakamas Tongcharoensirikul, a graduate student in chemistry, performs a traditional Thai dance known as the Srinual during WPI's 1993 Cultural Festival. More photos begin on page 19. Photo by Janet Woodcock. **Back Cover:** More than 5,000 graduates and their guests gathered on the Quadrangle for WPI's 125th Commencement on May 22. The theme of this year's ceremony was "Engineering and Science Education: A Future Agenda." Photo by Michael Dorsey.

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Globalization: The Next Big Wave

By Ronald L. Zarrella '71

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It's difficult to pick up a business or economic journal these days without reading something about the management of global marketing, global technology, global manufacturing or global finance. Globalization has joined total quality management as one of the most written about and talked about subjects in American business and industry. And as with TQM, successful globalization of business activities will be a fundamental element of competitive survival for the world's major industrial companies in the 1990s.

To appreciate why this is so, one need only look at America's changing economic role in the world. In constant dollar terms, the world's economy, expressed as total Gross Domestic Product, was $2 trillion in 1970; 20 years later, it was $15.7 trillion. In 1970, the U.S. economy was $1 trillion, fully half of the world's Gross Domestic Product. By 1990 it had dropped to a third of the world economy, or $5.4 trillion—still an enormous number, but with considerably less impact than it had two decades ago.

What has happened to Japan, our largest economic competitor? In 1970 its $200 billion economy made up 10 percent of world GDP. But by 1990, it had grown to $3.2 trillion, exceeding 20 percent of world GDP and doubling its economic influence. The world's third largest economy belongs to Germany. Somewhat surprisingly, its relative economic strength remained fairly constant over that same 20-year period, constituting around 10 percent of world GDP.

Another measure of relative economic strength is exports. This has been an area of strength for the U.S., where exports grew from 4 percent of GDP in 1970 to over 7 percent of GDP ($400 billion) in 1990. Japan's exports remained fairly constant at around 9 percent of GDP over that 20-year period (though they actually dropped from a high of 11 percent of GDP in 1980); they reached about $300 billion in 1990. Germany is the champion exporter, with 25 percent of GDP ($410 million) in 1990. Of course, net exports paint a much different picture, with the U.S. running a significant negative balance of trade over the last decade, and Japan and Germany running large, positive balances.

The last measure of relative economic strength I'd like to talk about is productivity. If we use Gross Domestic Product per worker as our measure, the U.S. is still the most productive nation in the world. In 1990 we produced $50,000 of GDP for every worker, compared to $30,000 in Japan and only $15,000 in Germany. But our enormously productive farming industry and our large financial and retail institutions distort this measure in our favor. If we look just at manufacturing productivity, the Germans are 10 percent more productive than we are and the Japanese are 20 percent more productive. In fact, the Japanese rate of productivity improvement is three times what ours is per year, although that gap is narrowing.

America is still the world's largest economic force and the world's largest market. We're an enormously productive people; we just don't have the dominance we had 20 years ago. We have to learn to play on equal terms with our economic competitors. We're no longer the only game in town. Many of us don't like that, but those of us who learn to do business in this new international economic environment will be the winners of the next decade.

Perhaps the most telling measure of industrial globalization is the percentage of revenue derived from outside the home country. For America's 100 largest industrial companies, the percentage of non-U.S. revenues grew from 14 percent in 1970 to almost 40 percent in 1990. For Japan's largest companies, the percentage is 57 percent; for Germany's, it is 69 percent. Furthermore, for U.S. companies, those revenues have shifted from being

derived largely from exports to being derived largely from products manufactured outside the country.

This last phenomenon is supported by a 15-fold increase in investment by U.S. companies manufacturing outside the U.S. In the same period, however, there has been a 30-fold increase in foreign manufacturing investment in the U.S. Both measures accelerated dramatically in the last half of the 1980s.

Consider Bausch & Lomb. As late as 1985, less than 20 percent of our revenues were derived from businesses outside the U.S. In 1992, 51 percent of our $1.8 billion in revenues came from outside the U.S. In 1985, 7 percent of our profit was derived outside the U.S.; in 1992, more than 60 percent was. In 1985, more than 80 percent of our products sold outside the U.S. were exported from the U.S.; in 1992, 80 percent of our products sold outside the U.S. were made outside the U.S.

This shift in the center of gravity of U.S. corporations has had significant implications for the way those corporations are organized and operated and for the kind of people who operate them. "Think globally, act locally" is today's catch phrase for organizational theory, but how to do that effectively is the subject of much debate and research. It is dependent on many factors, like the uniformity of products, the nature and cost of technology development, the location of core competencies and, probably most important, the corporate cultures involved.

A few traditional models define both ends of the organizational spectrum. On one end, there is the "global company." In the global company, functions—finance, marketing, manufacturing, product development and so on—are managed on a worldwide basis. Sales is the only real local function. Communications are simple: they flow out from the center and back into the center. The decision chain is also simple, with all key strategic decisions being made at the center. Companies organize this way because it is efficient.

Companies that have traditionally organized globally are those that have a high technology content, that are very capital intensive, or that have strong global brand names. Japanese companies are typically organized globally, as are the giant U.S. pharmaceutical companies. Coca-Cola is organized globally.

The other end of the organizational spectrum is the multinational. A multinational is organized around strong, independent, self-contained country units. The country general manager is the strongest executive in the corporation. Marketing, manufacturing, product development and finance are all done at the country level. The role of the corporate center is, simplistically, to collect the money and change the country management when there's no money to collect.

Companies organize this way because it puts decisions closest to the customer and best meets the needs of the local market. Many of America's great consumer packaged-goods companies and food companies are organized as multinationals. Unilever is a good example.

Harvard Business School professors Christopher Bartlet and Sumantra Ghoshol have developed the concept of the "transnational company," which they described in an important book called *Managing Across Borders*. In a transnational company, there is no real home country mentality. A transnational tries to achieve all the efficiency and synergy of a global company, with all the local responsiveness of a multinational. The structure fits with the corporate culture, but in a transnational, structure is less important than the operating mechanisms put into place to make the organization run.

A transnational makes the best use of its core competencies regardless of where in the world they are located. In a transnational, employees recognize that, while they are paid to perform a specific job in a specific location, they are part of a global enterprise. They have an obligation to learn from and contribute to that global enterprise, so they are better able to perform their specific jobs in their specific locations. The transnational creates an environment of continuous global learning. It creates a series of networks within the organization that do the work of the organization.

Advances in communications have made transnational companies possible; in fact, advanced communications are a critical requirement for them to work effectively. Today, relevant information is being made available on a real-time basis—and deeper into these organizations than ever before possible. Teleconferencing, videoconferencing and local-area networks interconnected on a worldwide basis are now being used widely, avoiding the need for large groups of people to jump on planes in order to meet face to face.

Networks of functional managers have worldwide information available to them. Product managers have market research on new and existing products from a number of different countries; marketing managers have competitive information available on global competitors; financial managers can coordinate currency hedges in multiple locations to protect a corporate balance sheet line item.

The strength of these communication technologies really comes into play in global product development. Television advertisements for the Ford Escort trumpet it as the "world car." Parts of it are manufactured and assembled in countries around the world, with final assembly in the U.S. At Bausch & Lomb, we've developed similar "world products" by learning to meet local market needs from a common technical platform.

We make a product called Interplak. The electromechanical design for this home plaque-removal device is done in the U.S.; the ergonomic design is done in Japan. The batteries are supplied from Japan, the motors are built in the People's Republic of China, the charging base is made in Hong Kong, the precision-molded plastic pieces are manufactured in Atlanta,

Bausch & Lomb's Interplak is a true world product, built from parts made around the world and modified to meet the needs of customers in 30 countries.

the brush head is made in Ohio, and the final assembly is done in Mexico.

To meet local, retail and consumer needs in 30 countries around the world, there are 50 variations of the same basic Interplak design. There are marketing managers, product design engineers, cost analysts and manufacturing managers in nine locations, all of whom work on product development for these products. Design and specifications are computerized at the design locations and electronically transmitted to the manufacturing sites for the various parts and assemblies around the world. When it is necessary to change a specification, the worldwide file can be updated on a real-time basis.

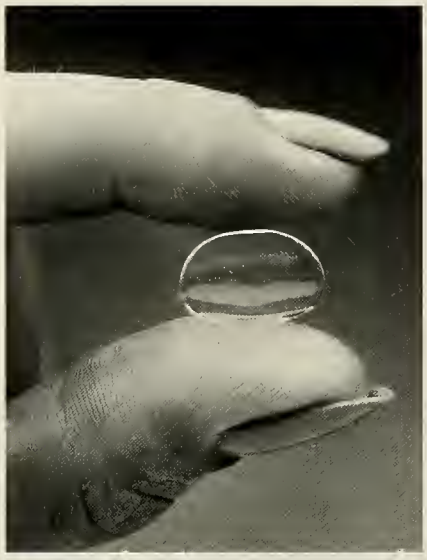
There is a network of 20 people who bring new products in this category to market, managing the process from idea generation to product launch. They meet face to face maybe twice per year. All the work gets done on an interconnected information network with regular use of video conferencing.

Here's another example. Ten years ago Bausch & Lomb's primary business was the manufacture of contact lenses, and that is still an important business for us today. The typical age profile of a contact lens wearer is 18 to 35. In the 35 to 40 age range, presbyopia starts to set in and a contact lens wearer needs bifocals. There really is no effective mass-market bifocal contact lens; the known technology simply doesn't work. As a result, a percentage of our market every year switches to wearing spectacle bifocals.

The technology does exist to individually manufacture a bifocal contact lens for a specific eye. On the surface, this is not a particularly interesting business for a company that makes millions of contact lenses at very low cost. The many design parameters that need to be taken into account in an individually manufactured bifocal contact lens result in hundreds of thousands of variations.

But an engineer in Holland came up with a concept that could manufacture these individually designed lenses at a very low cost. A doctor in Europe or the Middle East could call an 800 number in Ireland and access a voice-activated program. He would then input the specific values for the design parameters, which he would have measured on his patient.

The digitized information would be fed into a computer-controlled laser, a system developed by a U.S. company working in concert with engineers in the U.K., who, in turn, worked with scientists from the University of Manchester. The laser would cut the digitized design into a special polymer; within a minute of the information being taken from the doctor, a finished bifocal lens would be in a package ready to be mailed for delivery within 48 hours.



Making contact lenses for people ages 18 to 35 is an important part of Bausch & Lomb's business. A way of making individually designed bifocal contact lenses at a reasonable cost may open up the over 35 market for the company.

The production unit I've just described could manufacture up to 5,000 individually designed bifocal contact lenses a day at a cost well within the range of financial reasonableness. Four of these units, located strategically throughout the world, could supply worldwide market needs.

The skills required to succeed in this kind of environment have definite implications for scientific and engineering education. The hardware—the core science and engineering curricula and the way it is taught—is in place and is effective. University-level education in science and engineering in this country is widely regarded as the best in the world. The only criticism I have of the hardware is the lack of appropriate attention to the concepts and application of total quality management, although a groundswell is beginning to develop for additions to the curricula in this area.

The software—the nonscience-based classroom work and the experience outside the classroom—is a different matter. The fostering of acceptance and awareness of cultural diversity (further than that, the development of an intense, intellectual curiosity about cultural diversity) is a necessity in the educational program. But it is not really evident on college campuses today; in fact, the reverse seems to be true.

There has to be a recognition that because something is different, it's not necessarily better or worse—it's simply different. This skill doesn't come as naturally to us as it does to Europeans, nor do we work as hard at it as the Japanese. A Japanese company wouldn't think of sending executives to America to negotiate a business deal if they didn't speak English. Nor would those executives ask to have dinner at a sushi bar if they were with their American counterparts.

Yet American language capability is notoriously bad. We too often try to sell products designed only for U.S. markets, and we try to force our values and lifestyles onto our international counterparts.

There are many ways a college or university can encourage cultural diversity and perspective: language studies, specific cultural studies, increasing the number of foreign students, hiring international scholars, serving international food and creating diverse cultural support systems. All of these can work with the support and commitment of the leadership and the faculty.

WPI is uniquely positioned to provide national leadership in global science and engineering education. I was a senior when the faculty approved the WPI Plan. The guiding objective of the Plan is simple: to educate humane technologists.

By pursuing that objective, WPI has already put in place most of what is needed to create successful global technologists, including the requirement that students work on cross-functional teams to solve problems; the requirement that they supplement scientific studies with studies in the humanities and social science, including, for many, work at global project centers; and the courses and projects that give them the ability to work on real problems in different cultural environments.

The Plan puts WPI on the leading edge of the wave. And I firmly believe it will be a very big wave.

Zarrella is president of Bausch & Lomb Inc., a leading worldwide manufacturer of healthcare and optics products. This essay was adapted from Zarrella's address to the WPI Workshop on Internationalizing Science and Engineering Education held in Waterville Valley, N.H., in October 1992.

The Whole World in Their Hands

By Diane Benison

Through WPI's Global Perspective Program, students have traveled the world to complete professional-level projects. The program is also building a growing base of globalization programs and curricula here on campus. The goal is to help students better understand their roles as working professionals and citizens on an ever shrinking world.

Marshall McLuhan's 1967 book, *The Medium is the Message*, became famous for its observation that, "the new electronic interdependence recreates the world in the image of a global village." That easy to grasp word-picture had a vividness that resonated instantly for his readers. But more than two decades ago, the interdependence McLuhan described was still an abstraction for most people.

Today, the global village no longer refers merely to the real-time connection of people via phone, fax, modem and satellite. Now, human society around the world is being transformed by the melding of hundreds of national economies into a single world market (see Input, page 2).

Volumes have been written about the globalization of business, technology, manufacturing and finance. In 1992, *Business Week* marshaled the efforts of nearly 200 reporters, editors and other staffers to produce a special issue on the global economy and its impact on the United States. If the U.S. is to retain its vitality as a nation and a world-class economy, the editors concluded, new ways of thinking and acting are needed.

Part of the responsibility for changing our ways of thinking and acting will fall to educators. From elementary school to graduate school, educational institutions are grappling with the need to develop curriculums and classroom experiences that prepare students to function effectively in a future that promises greater contact between cultures and more diversity in all aspects of life.

Those young men and women will find a world waiting for their skills. A recent survey by McKinsey & Co. found that most corporate CEOs recognize the increasing importance of international markets to the success of their companies. These firms will be looking for employees with the experience, skills and cultural awareness to help them succeed internationally.

That means being able to design and build products that will sell in diverse markets around the world and to work effectively with fellow employees, consultants and customers who live in other nations. And it may well mean being ready to relocate to corporate offices, divisions and subsidiaries outside the U.S. In short, it means that the professionals of tomorrow must be more than competent engineers, scientists and managers. They must be true citizens of the world.

WPI Students Travel the Globe

WPI currently operates project centers, project programs and exchange programs in 15 countries on four continents; new programs are added frequently. Project centers are staffed by full-time WPI faculty members throughout the seven-week periods that students are in residence.

While project programs do not have resident WPI faculty advisors, the Institute hires local advisors and coordinators to work with students. On-campus advisors often visit project programs briefly while students are on site.

Some project programs, such as the one in Ireland, are conducted in conjunction with universities with which WPI maintains exchange programs. Students may also do traditional year- or semester-long exchanges with these universities, taking courses in English or in the language of the host country. Some students complete a project during their exchange.

1 **Worcester Polytechnic Institute**
2 **Washington, D.C., Project Center**
3 **Ecole Polytechnique Exchange, Montreal, Canada**
4 **San Francisco Project Center**

Worcester Polytechnic Institute has been on the cutting edge of the globalization of technological education for two decades. Among experts familiar with WPI and with science and engineering education in the United States, the Institute is considered the national leader.

In 1992, Maurice Harari, a nationally known leader in international education, was asked to evaluate the Institute's global programs. Harari, dean emeritus at the Center for International Education, California State University at Long Beach, delivered his report in January. "I have no hesitation in asserting that WPI is way above the national average for its type of institution in terms of what it has already accomplished in the field of global education," he wrote.

"The flexibility and innovative character of its curriculum through the IQP, MQP, and Humanities Sufficiency, and the flexible WPI calendar arrangements, have contributed greatly to the achievements of WPI to date. Yet, its potential in global education is considerable and because of its rather unique institutional character and high quality, WPI is very well-positioned to aspire to a national and international leadership role in higher education. Its interest and experience in working at the intersection of

5 Puerto Rico Project Center
6 Ecuador Project Center
7 University of Limerick Exchange, Limerick, Ireland
8 London Project Center
9 Ecole des Mines and The University Marne-La-Vallee Exchange, Paris, France
10 Catholic University Exchange, Leuven, Belgium
11 Technical University of Darmstadt Exchange, Darmstadt, Germany
12 Technical College of Munich Exchange, Munich, Germany
13 Federal Technical University Exchange, Zurich, Switzerland
14 Venice Project Center
15 Moscow Institute of Engineering Physics Exchange, Moscow, Russia
16 Royal Institute of Technology Exchange, Stockholm, Sweden
17 Bangkok Project Center
18 Hong Kong Project Center
19 Taipei Project Program

technology, the sciences and social issues, represent a sound and invaluable base for yet another quantum leap forward in quality, service, innovation and international reputation."

WPI's leadership can be measured in several ways. For example, a recent Institute of International Education survey of study-abroad programs at colleges and universities, found that about 71,000 students enrolled in accredited U.S. institutions studied overseas in 1989-90. Of that number, only 1.3 percent were engineering majors. During that same period, 111 WPI students completed project work abroad. Among those 111 students were 86 engineering majors. They represented nearly 10 percent of all U.S. engineering students who studied overseas that year.

Currently, about a third of all WPI undergraduates participate in an off-campus academic experience by the time they graduate. The Institute's strategic plan calls for increasing that to half of all undergraduates by 1995. "I don't think that's an unrealistic goal," says Susan Vernon-Gerstenfeld, adjunct associate professor of interdisciplinary studies. "So far, the quality of the students who participate has been quite high. This is a selective program, but we're not just taking the superstars. We're also taking the steady, hard workers who show real promise.

"This is not a junior year abroad program of the kind that are common at liberal arts colleges. It is also not an internship. These students are not pouring coffee and running errands. They're working on applied research that is substantive and important to the sponsoring organizations. And, those organizations *use* the results of the students' work; I think that's a critical thing to understand."

The Institute laid the groundwork for national leadership in global education when it created the WPI Plan in the early 1970s. Two elements of the Plan have been key to the evolution of the Institute's global program. The first is the Interactive Qualifying Project (IQP). One of

LISA RICHARD UANUEW

Hossein Hakim, left, and Lance Schachterle have played pivotal roles in launching and sustaining WPI's Global Perspective Program. Schachterle helped establish the Institute's first overseas academic endeavors. Hakim helped start the Center for International Studies and is now WPI's Global Program Officer.

three projects required of all undergraduates, the IQP requires students to look at the intersection of science, technology and society. The second critical element is an academic calendar based on seven-week terms.

Lance Schachterle, associate dean of undergraduate studies and chairman of the Interdisciplinary Studies Division, says WPI's globalization efforts occurred as a natural, though unanticipated, outgrowth of the Plan. "When the Plan shifted the focus of learning at WPI from a traditional pure course work approach to a project-based model, the integration of learning into real-world experiences became the basis for earning an undergraduate degree," he says.

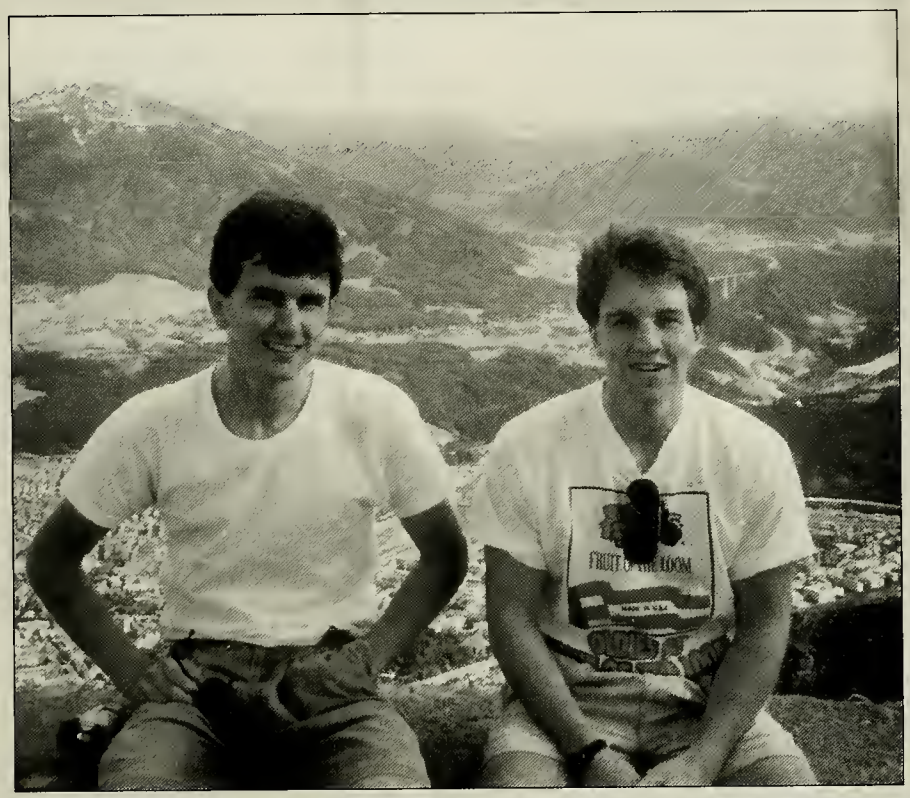
"It occurred first to the faculty and then to the students that the IQP offered us an opportunity unavailable at all other universities. Students have to complete this degree requirement in any case; why couldn't they carry it out beyond the bounds of the campus? In fact, there seemed no reason why this requirement couldn't be met anywhere in the world. It made a lot of sense for students who were looking for an opportunity to gain international experience within their four years to do so through a project abroad, rather than through an extra summer or semester."

Making that idea even more attractive was WPI's seven-week term system. In seven weeks, a student can do significant project work off campus without losing ground in meeting the rigorous and extensive course requirements typical of colleges of engineering and science. The semester system common at other engineering and science institutions can pose more of a barrier, Schachterle says.

Schachterle, who joined WPI in 1970 to teach modern British literature, played a pivotal role in launching the Institute's globalization program more than two decades ago. Though he had done his doctoral dissertation on Charles Dickens, Schachterle had never been to England. When he made plans to travel there in the summer of 1971, WPI, which had made contact with a university in London, asked him to help pursue an exchange program with that institution.

"That led directly to the first WPI students carrying out any kind of academic work overseas," he says. In addition to the London exchange, an exchange program was also established in Zurich during the 1973-74 academic year. The first overseas IQPs were completed through these programs. The Institute's first resident project center was founded in Washington, D.C., in 1974; a project program was launched in San Francisco a few years later.

Studying Culture and Computers in Switzerland



Paul Szymkiewicz, left, and Steven Vassallo pose before the backdrop of the Swiss Alps. The students completed an IQP that looked at how Switzerland's unique culture affects the way people react to new computer technology.

Change is inevitable in a progressive society. Change is constant." Benjamin Disraeli was referring to the society of 1860s Britain when he wrote those words, but most leaders in our technological society would agree they seem more true today.

Paul M. Szymkiewicz '93 and Steven P. Vassallo '93 spent their junior year as exchange students in Switzerland, where they took courses and completed an Interactive Qualifying Project titled "The Cultural Implications of Computerization in Swiss Banking." The students' project explored the reciprocal relationship between culture and the implementation of new technology.

Through personal interviews and a survey (both completed in German), as well as personal observations, the students analyzed the impact of culture and technology on the organizational and work processes within Swiss banks. Robert E. Kinicki, associate professor and head of the Computer Science Department, and Lyle E. Wimmergren, associate professor of management, were the project advisors.

While in Switzerland, Szymkiewicz studied computer science at the Engineering School HTL in Brugge-Windisch; Vassallo studied mechanical engineering at the Swiss Federal Institute of Technology in Zurich.

Vassallo prepared for the exchange by completing a six-course Humanities Sufficiency (the equivalent of a humanities minor) in German at WPI. He then continued his studies in Germany for two months before traveling to Zurich in August 1991. Szymkiewicz emigrated with his family from Warsaw to West Germany in 1986 and completed high school there. The family moved to Worcester in 1989.

The idea for the IQP came from Kinicki, who spent a year as a visiting professor at the Business School in St. Gallen, Switzerland. He observed that the Swiss were still in the process of scrambling to implement information technology in their everyday lives, and that the difficulties seemed rooted in Swiss culture.

"We recognized that introducing new technology into an organization can affect the values, norms and assumptions of the members," says Vassallo. "We were aware that because Switzerland has been geographically, economically and, perhaps, emotionally isolated, the country has traditions and a culture all its own."

"We knew that Swiss banks were some of the most technologically advanced in the world," adds Szymkiewicz. "But we hypothesized that, because of workers' cultural resistance to change and the inherent differences between banking and computer subcultures, the Swiss might have been reluctant to accept the new computer technology. We called this phenomenon 'cultural inertia.'"

The students created a survey geared to the average Swiss citizen; additional questions were added for those who interact with computers and banking as professionals. They found that younger respondents were most likely to recognize the need for technological change. Nonetheless, regardless of the bankers' ages, efficiency triumphed over tradition and technology was accepted.

But just as important as the project's ultimate outcome, was the profound impact it had on its two designers, Vassallo says. "As exchange students in Zurich, we had an incredible opportunity to gently open a very closed culture and have a look inside. Most impressive, however, was not what we saw, but rather how we now see."

"As Americans, as engineers, as students—most generally speaking, as humans—we see the world in a certain way," adds Szymkiewicz. "We evaluate the world without ever evaluating the lens through which we are looking. It is only when we leave behind our old perceptions and try looking through a different lens that we really make a shift in the way we see the world."

—Bonnie Gelbwasser

Ireland became a regular destination for student project teams in 1983 and the first overseas project center, in London, was inaugurated in 1987. More recently, project programs have been established in Venice and Bangkok (1988), Hong Kong (1989), Taipei (1990), Puerto Rico (1991) and Ecuador (1992). Today about 200 students each year work at project centers and programs in 18 locations in Europe, Asia, North America and Latin America (see map, pages 6 and 7).

The international projects program fed on its own success, and succeeding years saw a growing demand among students for overseas project opportunities. At the same time, there was a groundswell of interest in cross-cultural issues among the faculty and administration. In 1988, that interest culminated in the creation of the Center for International Studies on campus. The center sought to expand opportunities for international studies at WPI by arranging study groups and lectures, organizing tours abroad, and encouraging faculty to develop and advise on-campus projects with an international orientation. Hossein Hakim, associate professor of electrical engineering, led the efforts to establish that center.

"Historically, international education has meant study abroad," he says. "We now realize that, at least for the U.S., study abroad is not just a route to understanding people in other countries. It is also a way of understanding and learning to cooperate with other Americans who have come from other parts of the world—people like myself."

An Iranian native who is now a naturalized U.S. citizen, Hakim had long believed in the benefits of globalizing education. He says he saw the center as one more way to encourage a world perspective at WPI. But he says he and others at WPI didn't feel it was enough. They believed that international issues and cross-cultural perspectives needed to be interwoven into on-campus courses and activities, as well.

By 1990 it was clear that WPI had the interest and the capacity to take the next step on the road to global education by making a concerted effort to make global issues an integral part of all aspects of a WPI education. Hakim, Schachterle and several other faculty members and administrators persuaded the Institute to establish the Global Perspective Program. The program was launched in 1991 with Hakim assuming the additional responsibilities of Global Program Officer.

"The goal of the program is to extend WPI's commitment to global education far beyond the international exchange and project programs," Hakim says. "It calls for globalizing all aspects of WPI programs—on campus and off—by incorporating global perspectives throughout every discipline on campus, as well as within nonacademic activities."

By 1991, when the Global Perspective Program was started, WPI had a small cadre of faculty members and administrators who were dedicated to the globalization of engineering and science education. To help spread the word and build enthusiasm among the rest of the WPI community, Hakim organized an off-campus workshop on internationalizing science and engineering education in October 1992. Forty-five faculty members, administrators, trustees and friends attended the weekend seminar in Waterville Valley, N.H.

An additional seminar was held on campus in February 1993. Both meetings examined the changing nature of national economies, the history and present state of "internationalization" in higher education, and most important, the history and future

JANET WOODCOCK

Professor John Zeugner, left, and Phanjar Ngamtrakulpanit '93 of Thailand look over a map of Southeast Asia. Zeugner, who directs WPI's project programs in Asia, helped get the first Asian program started in Bangkok, Thailand, in 1988.

Breaking Down Barriers in Russia

MICHAEL DORSEY

Back from a four-month exchange in Russia, Ronald Passerini, right, reviews his experiences with his faculty advisor, Professor Valentin Boriakoff.

In August 1992, Ronald Passerini '94, a computer science major, turned a nearly lifelong affection for all things Russian into a four-month exchange in the former Soviet Union. He was the first WPI student to fulfill some of his degree requirements in Russia; he was also the first foreigner to study at the Moscow Engineering Physics Institute (MIFI), a prestigious, 3,500-student university. Until recently, the institution was closed to outsiders because its curriculum focused on fields of special interest to the government, including atomic power and space research.

"My interest in Russian history, language and literature started when I was about 6 and became close friends with a boy whose family had emigrated from Russia," Passerini says. "I became close to his family, who invited me to share many of their traditions and celebrations." Passerini studied Russian for four years at Austin Preparatory School in Reading, Mass., and another three years at Holy Cross College after enrolling at WPI.

Valentin Boriakoff, associate professor of electrical and computer engineering, was Passerini's faculty advisor. Boriakoff, who was born and educated in Argentina but maintains close ties to Russia, his parents' homeland, traveled to Moscow during the summers of 1991 and 1992 to set up the exchange.

"Interest in computer science in Russia is very high," Passerini says. "Unfortunately, there aren't that many computers available. About 10 years ago Russia stopped producing computers and now it is difficult to buy them from the West because of the exchange rate."

In his IQP, titled "From the Abacus Bead to the Photon: A History of Computer Technology in Russia," Passerini investigated the causes of the decline in the use of computers. "He determined that a wrong government decision derailed a creditable native computer industry," Boriakoff says. "MIFI faculty were interested in his project because they are studying the same problem. Ron researched aspects of Russian computing history completely unknown in the West.

"Because Ron has made such a fine impression on the people he worked with, we expect to offer more WPI students opportunities to study and complete IQPs and MQPs in Russia in the future. Ten students have already expressed interest in these projects."

In addition to his IQP work, Passerini took two courses in Russian. "When I first got to Moscow I thought, 'I'm 5,000 miles from home, I don't know anyone, and I'm not fluent enough in the language to get through this.' But everything worked out fine."

An unexpected opportunity presented itself to Passerini during his Russian visit. "One day I was feeling homesick and craving American food, so I walked downtown to the Pizza Hut on Tverskaya Street," he says. "I was wearing a WPI sweatshirt and when I took off my jacket, a guy sitting across from me jumped up and said, 'I don't believe it. I graduated from WPI in 1963!'"

It was Harold Taylor, manager of international programs for United Technologies Corp., who travels frequently between Moscow and company headquarters in Windsor Locks, Conn. "We became friends and he invited me to send him my resume before I graduate," Passerini says. "I'd love to work there for a few years, but not forever. America will always be home."

—Bonnie Gelbwasser

of WPI's own Global Perspective Program.

The program has also gained momentum through a two-year, $123,000 grant from the U.S. Department of Education. Hakim is using the grant in a variety of ways to further the infusion of globalization at WPI. Some of the money is helping faculty members revise course content and further their development and interest in globalization.

One of those faculty members is Karen Ruhleder, assistant professor of management, whose research focuses on management information systems, social and organizational aspects of computing, and computer-supported cooperative and collaborative work. Ruhleder is developing a teaching case study based on the formal unification of the East and West German governments.

Although Berlin is once again the seat of government for the unified Germany, some critical work is still done in Bonn. The two cities will be connected with modern information and communication technologies, Ruhleder says. She will investigate a government-sponsored project called POLIKOM, "a multiphase, multiparty effort to design and implement the technological and organizational changes required to support work across such physical distance," she says.

Probing Environmental Issues in Ecuador

In December 1992, John P. Coyle '94, Daniel R. Dibiase '95 and James A. Watson '94 comprised one of two project teams that inaugurated WPI's new project center in Guayaquil, Ecuador. The students completed an Interactive Qualifying Project that has already had an impact on the future of the center and WPI's work with ESPOL, a technological university in Guayaquil.

The students first prioritized Ecuador's major environmental issues and developed a plan for future projects by WPI students. They next analyzed the environmental and socioeconomic impacts of the new Esmeraldas-Santo Domingo Poliduct, a 160-kilometer pipeline that transports oil and gas to Ecuador's coastal region. They determined that the country's poliducts have had negative consequences, including land scarring, erosion, and damage to vegetation and wildlife caused by leaks or ruptures in the pipeline.

"The good news," they note, "is that because of heightened social concerns about the poliducts in recent years, the Ecuadoran government has felt pressure to enforce environmental protection laws. While the laws can sometimes be contradictory, they can ultimately be used effectively to reduce the impact of the pipeline."

An Ecuadoran student (center, without shirt) poses with, clockwise from left, John Coyle '94, Joshua Dobbelaar '94 and Daniel Dibiase '95. In late 1992, Coyle, Dobbelaar and Dibiase were part of the first group of WPI students to complete projects at the new Ecuador Project Center.

James E. Rollings, associate professor of chemical engineering, served as the first director of the Ecuador center. He is also director of the Latin American Project Programs at WPI and a W.K. Kellogg National Leadership Fellow. Along with Guillermo Salazar, associate professor of civil engineering, and Daniel Tapia Falconi, co-project director at ESPOL, Rollings served as advisor for this initial project.

"It was important for the students to see the relationship between technology and society," Rollings says. "By looking at one example—the new poliduct—they could see the interrelationships that develop with other sectors of society. The insights they gained enabled them to identify six areas of environmental concern specifically related to the poliduct: the impact of the oil industry on the Amazon River, reforestation, low-technology projects, the pollution of the Guayas River, the impact of the mining industry, and ecotourism. These will be considered as potential topics for future IQPs."

Francis C. Lutz, dean of undergraduate studies at WPI, Carlos Becerra, ESPOL's vice rector, Frederick L. Hart, associate professor of civil engineering at WPI, and Salazar have applied for funding to promote the exchange of faculty between the two institutions and to initiate the development of joint research by establishing a database system to be used in identifying and addressing

"The participants see POLIKOM as a testbed for other members of the European Community and for international corporations."

Ruhleder says she believes a case study based on POLIKOM can be used in courses in management information systems, telecommunications, international business and public policy. "To consider non-U.S. scenarios, students must relinquish their ideas and expectations about how things work and refine their own understanding of the cultural factors that contribute to organizational decision-making and the mobilization of support for potentially controversial projects," she says.

"She's going to learn something that will help in her research," Hakim says, "but her experiences will also help her revise her courses on management information systems. She'll bring something back to the college that will help students." Hakim says he is using the Education Department grant in a similar manner to help other faculty members infuse global issues into many other areas of the WPI curriculum.

Hakim is also using the grant to provide seed funding for international student programming, cultural festivals and similar activities. The grant also brought SCOLA (Satellite Communications for Learning) to campus. SCOLA delivers TV news from more than 30 countries in 20 languages to television sets across campus, providing a non-U.S. view of world events and allowing students to hear other languages spoken by native speakers.

And, the grant is being used to support the WPI-Worcester Public Schools Alliance for Global Education. Through the alliance, WPI faculty are working with public school teachers to develop a global education program for grades K through 8.

Hakim recently completed a cost analysis of the Global Perspective Program. "The results were quite interesting," he says. "One might think that maintaining programs at 18 sites around the world would require a huge investment. But the analysis indicated that the academic work done off campus would actually cost more if it were done on campus."

Hakim says there are several reasons for this. One is the support the program receives from alumni and friends around the

James Watson '94 stands beneath a section of the 160-kilometer Esmeraldas-Santo Domingo Poliduct, an oil and gas pipeline in Ecuador. Watson, Coyle and Dibiase looked at the potential environmental impacts of the poliduct.

environmental issues for the Guayaquil region.

The proposed research includes a provision for an ESPOL faculty member to spend two years at WPI studying for a master's degree; the plan of study would include courses in environmental engineering, construction management and computer information systems. "The faculty member would also work with a WPI research assistant on the database project, lecture and assist with our ongoing projects at the Ecuador Project Center," Salazar says.

"The database we propose will help us address issues that relate to the pollution of the Guayas River," he says. "The students' work complements what we are proposing. They did a first-class job of organizing and classifying areas for major future research and have given us a strong foundation upon which to build this and future proposals."

—Bonnie Gelbwasser

world, all of whom volunteer their services. Another is that, for the most part students pay their own transportation and housing costs when they travel overseas. (WPI subsidizes housing costs in Washington, D.C., where living expenses are quite high, and some students receive additional financial aid when they are abroad to partially offset their expenses.)

Some economies result from the fact that the average size of an overseas project team is three students, versus two students for a typical IQP team on campus. In addition, resident faculty advisors at project centers work with an average of 15 students at a time, a project advising load that would be difficult to handle back on campus. And, since one-third of students who go abroad to do projects do so during the summer, when they must pay additional summer-session tuition, the program actually brings in extra revenue for the college.

"Although the financial analysis of the program looks quite positive," Hakim says, "we should not limit our analysis to cost comparisons. There's no way to put a dollar value on what the experience does for WPI's graduates. In letters and conversations, alumni have told me and other faculty members how their experiences abroad have given them a competitive edge in their jobs. We plan to do a survey of alumni this summer to better understand this impact.

"It's also difficult to quantify the value of diversity. If you want a more diverse campus, you have to have people who think differently. I think the Global Perspective Program helps create a more tolerant environment on campus. And, it's also difficult to measure the important role the program plays in attracting—and retaining—students, something not to be overlooked in the fiercely competitive environment for higher education today.

"Many of our competitors look at their global programs as a way to make themselves more attractive to students. There is a growing interest among students in such programs, and these schools are increasing their investments in them. We must be careful not to lose our lead."

As he looks to the future of the Global Perspective Program, Schachterle says he is pleased that several faculty members are expanding the global projects program beyond the IQP by developing programs through which students will complete their Major Qualifying Projects—the capstone project in a student's major field of study—in England, Germany and several other countries. Opportunities are also growing for completing cooperative education abroad, he says, and the globalization program may well play a significant role in the development of the Institute's graduate programs and research collaborations.

Earlier this year, the faculty voted to modify the humanities requirements to enable students to cap their humanities course work with a full term of project work abroad. "This is a wonderful chance for WPI students to study theater in London, for example, or the arts in Venice," he says.

"Through initiatives like these, WPI is poised to achieve the role of national leader in global education within the community of engineering and science institutions. Companies that need technically able professionals who can live and work effectively in cultures new to them increasingly will look to WPI graduates to fill that need, because our students, among all graduates of engineering and science colleges and universities, will be uniquely qualified to help their employers compete successfully in the global village."

Faculty members who have advised IQPs abroad or helped launch overseas project programs and centers recount similar tales about what can sometimes be a difficult process. All say one must first educate potential sponsors about the WPI project orientation and its seven-week terms and then convince them that WPI undergraduates can indeed function as professional consultants.

Veterans of the process, like Schachterle,

JANET WOODCOCK

From left, Mary A. Burke '93 and Matthew R. Boutell '93 discuss their Interactive Qualifying Project with Susan Vernon-Gerstenfeld, director of the Puerto Rico and Washington, D.C., project centers. Working for the Concillio de Diseno y Technologia in Puerto Rico, Burke and Boutell developed strategies to help Puerto Rican apparel manufacturers market their products in the U.S.

Vernon-Gerstenfeld and history professor John Zeugner say foreign-born alumni have often lent their reputations and support to help WPI gain a toehold in their home countries. Once the college, with the help of these graduates, has laid the groundwork with an inaugural student project, other prospective project sponsors are often significantly more receptive to the idea of working with WPI's undergraduates.

Zeugner is director of the International Scholars Program and the Asian Projects Program. The International Scholar designation is a special notation on a graduate's diploma and academic record indicating he or she has completed a Humanities Sufficiency involving a foreign language or culture, and either completed an IQP or MQP at a foreign project site or spent at least a half year as an exchange student at a foreign university. Twenty-four graduates have earned the designation since the program was started in 1989; 19 candidates are enrolled in the Class of 1994.

Zeugner taught in Japan for four years, first as a Fulbright Senior Lecturer between 1976 and 1978, then as a visiting professor of American culture in Tokyo between 1981 and 1983. Next year he will return to Japan as the Bryan Drake Guest Professor at Kobe University. He has also lectured in Manilla, Bangkok and Taipei for the United States Information Agency. At WPI, it's his job to make sure the college has projects in Asia, and that students have housing, on-site advisors, WPI advisors, and any other assistance and guidance they need.

His story about launching the first project in Thailand illustrates the role cultural differences can play in the process. "WPI has a lot of good contacts in Asia," he says, attributing many of them to Yi Hua Ma, professor of chemical engineering, Roy A. Seaberg Jr., director of special admissions, and WPI's active network of alumni in Thailand. "Making initial contacts was relatively easy. But Thais prefer face-to-face contact for conducting new business, and that meant the usual WPI preparation process had to be altered as the first Thai project was getting underway.

"Normally, the preparatory work includes doing background stuff on the country and its culture, completing a preliminary bibliographic assessment for the project, and writing a full project proposal that is sent to the sponsor. The sponsor reacts to the proposal and gives you feedback before you arrive, so everybody agrees what they're doing."

To ensure a successful start in Thailand, Zeugner traveled there with the first team of students to get them set up, to make sure the sponsor and the team had the same understanding of the project's goals, and to be sure the sponsor was comfortable working with undergraduates.

"The biggest hurdle we have in Asia is similar to the hurdle we face in London," he says. "There is a profound cultural assumption that undergraduates are children and not suitable for any kind of serious intellectual endeavor or rigorous academic inquiry. In London and in Bangkok, the assumption is that they're just not mature, that they cannot do serious, competent work. These are societies that value age.

"It's important for our undergraduates to learn things and be taken care of, but when we go to Bangkok and say, 'our students can perform work and do analysis for you that you will find helpful,' it's like me saying to an American, 'I've got these fourth-graders who will help you.'"

To overcome this cultural bias, WPI has allied itself with universities where the faculty believe undergraduates—especially WPI students—can do useful work. Another strategy WPI employs in countries where the cultural imperative works against taking undergraduates seriously, is to do the first projects with nonprofit organizations, as they are usually quite receptive to the idea of free help.

"In Taipei, for example," Zeugner says, "I could get 100 projects in the area of technology to assist disabled children. In fact, we've had a wonderful series of projects

Improving Commercial Fishing Safety in Washington

Being a commercial fisherman involves more than just casting a line or hauling in a net full of cod. Studies indicate that many boats are unsafe and crew members often unprepared to deal with the complexities of trawling for seafood.

One of the U.S. Coast Guard's main responsibilities is maritime safety. The passage of the Commercial Fishing Industry Vessel Safety Act of 1988 established a comprehensive set of safety regulations for the industry and gave the Coast Guard the authority to enforce them. The problem is that there is no effective, cost-efficient way to reach owners of vessels to inform them of the regulations, making enforcement a hit-or-miss proposition.

Trevor G. Hebert '94, Shannon M. Willems '94 and Stephen J. Lanczycki '94 worked at Coast Guard Headquarters during a seven-week stay at WPI's Washington, D.C., Project Center in 1992. While there, they created a database that will enable the Coast Guard to provide detailed demographic information on the owners of state-numbered commercial fishing vessels, which represent 76 percent of the commercial fishing fleet.

The students also created *The Commercial Fishing Safety Communication Manual.* It includes detailed descriptions of how Coast Guard personnel can obtain a list of state-numbered commercial fishing vessel owners from the 30 coastal and Great Lakes states. It provides the name and address of the person or office in each state to whom inquiries should be sent, the name and address of each state's boating law administrator, the cost of obtaining the information, the number of state-numbered commercial fishing vessels operating in each state, and any special procedures required by individual states to obtain information.

"The project filled a void the Coast Guard wasn't able to address because of limited resources and time," says Tim Farley, a civilian fishing safety specialist for the Coast Guard's Fishing Vessel and Offshore Safety Branch. "They determined how best to disseminate information to the many diverse fishing communities nationwide."

Hebert, Lanczycki and Willems recommended that a coordinated effort by the Fishing and Offshore Safety Branch, the Auxiliary, Boating and Consumer Affairs Division of the Office of Navigation Safety and Waterway Services, and the Management Division in the Office of Marine Safety, Security and Environmental Protection be established. These divisions could collect the new data and combine it with information on documented vessels that is contained in an existing database known as the Marine Safety Information System.

They also recommended that the Coast Guard create and use the database to distribute safety information nationwide, preferably in the off-season, and to distribute information and advertise local regional safety programs. "A coordinated effort to distribute safety information could have a major impact on improving safety in the industry," they concluded in their report to the Coast Guard. "Direct mailing will probably be the most effective method of communication. With a complete and accurate database of all commercial fishing vessel owners, nearly all can be contacted."

"Our officers have discussed and evaluated the students' recommendations and will ultimately coordinate implementation with Coast Guard programs having expertise in data processing and communications," Farley says. "These programs will then assume responsibility for carrying out the steps necessary to achieve the desired results—better communication with all fishermen working in the United States."

—Bonnie Gelbwasser

PHOTO COURTESY OF U.S. COAST GUARD

To help it fulfill its mission of protecting the safety of the nation's commercial fishing fleet, the U.S. Coast Guard sponsored a team of WPI students who compiled information that will help the agency reach fishing boat owners.

in that area, which is an important issue in Taiwanese culture." The project that won WPI's 1992 President's IQP Award was done in Thailand with a nonprofit agency (see story, this page).

After the Bangkok project program was established, Zeugner hired Prapaipit Chamsuksai as the on-site advisor for IQP projects in Thailand and also made contact with Supawan Tantayanon. Among more than 60 WPI alumni in Bangkok, both women received their doctorates at WPI and are professors at Chulalongkorn University. Chamsuksai won WPI's outstanding teaching assistant award in 1988, the year she received her doctorate in chemistry. "They have been absolute gems in terms of advising projects, getting projects and making the connection between WPI and Chulalongkorn," he says.

Zeugner says he believes the projects completed over the last few years have begun to change people's perspective about WPI students. "I think we're also getting more sophisticated in making contacts," he says. "We now have many more projects than we can staff in Bangkok. We recently turned down a major corporation because the students weren't interested in that project."

WPI's new emphasis on Latin America began in 1991 when the college received a $150,000 grant from the Xerox Foundation to establish a project center in San Juan, Puerto Rico. "Puerto Rico is interesting," says Vernon-Gerstenfeld, who directs the Puerto Rico and Washington project centers and the Ireland project program. "While it is part of the United States, it is also part of Latin America. The island acts as a bridge. We conceived of it as a place where our students would get good training in multicultural issues and gain intercultural experience by working in an environment that is Latin, and yet still quite familiar.

"Puerto Rico looks a bit like Miami and has the same stores you see in Worcester or Boston. But when you're working in an office, the environment is much more Latin. Also, people from elsewhere in Latin America come to Puerto Rico to live and work, so you learn about Cubans, Ecuadorans and so on. It's a tremendous place to learn about other cultures.

"One of our explicit goals in San Juan is to help correct misperceptions about Puerto Rico and Puerto Ricans. We want to help students understand that their stereotypes are just that and don't have

Reaching Out to Slum Dwellers i

Last year Jason D. Herrick '93, Michael R. Passe '93 and Gunther Schrappe '94 completed their Interactive Qualifying Project with the Duang Prateep Foundation (DPF), a nonprofit organization in Bangkok, Thailand. The students studied the chemical storage policies of the Port Authority of Thailand (PAT). The foundation was interested in this information because in March 1991 a chemical explosion leveled three warehouses at the PAT facility in Klong Toey, a heavily populated Bangkok slum. The explosion killed five people and injured countless others.

DPF, which is devoted to improving life for residents (especially children) of the Klong Toey community, asked the WPI students for help in educating slum dwellers about the chemicals involved in the explosion and in preventing future accidents. The team analyzed the effects of the explosion and did a series of chemical investigations to find out how the explosion might have occurred.

PAT, which stores chemicals adjacent to the slum, never released a full listing of the chemicals kept there. "PAT put out a list of 10 chemicals," notes John F. Zeugner, professor of history and the students' advisor. "The students, through their investigation, drove that list up to 53 chemicals. Using soil and water residues, they did their analysis with the help of Professor Prapaipit Chamsuksai at Chulalongkorn University. They also interviewed slum dwellers about the symptoms they experienced. The students noted that many unidentified chemicals had been stored at the warehouses."

Team members reviewed international storage procedures and studied chemical explosions. They designed and wrote a pamphlet for DPF to distribute to doctors, community leaders and residents and a poster for distribution within Klong Toey. They were interviewed by local television and they wrote a commentary for the op-ed page of *The National*, a major English-language newspaper in Bangkok.

Although PAT had not announced any

Bangkok

intention to modify its storage facilities or practices by the time the students left Thailand, the team's work prompted a public outcry over the policies of the Port Authority and a consensus that the government needed to do more for the victims of the explosion.

Prateep Ungsongtham Hata, the founder and president of the foundation, grew up in Klong Toey. Her work to improve life for residents of the slum has been recognized locally and internationally. In Thailand, when she was awarded the Magsaysay Award, the King commissioned 100 commemorative coins to honor her. She was so pleased with the WPI team's work that she gave each member one of those coins. The judges for the 1992 competition for WPI's President's IQP Award were also pleased. They awarded the honor to Herrick, Passe and Schrappe.

—Diane Benison

Gunther Schrappe '94 (far left, back row), Michael Passe '93 and Jason Herrick '93 (third and fourth from left, back row) pose with staff of the Duang Prateep Foundation in Bangkok. Foundation founder Prateep Ungsongtham Hata is in the front row, second from right. Working with the foundation, the students analyzed the aftermath of a chemical explosion in the Klong Toey slum and developed programs to educate residents about the effects of the chemicals. Below, the Flats, part of Klong Toey, sits next to the remains of a residential area destroyed in the explosion. The foundation is dedicated to improving life for slum residents, especially children, opposite.

a whole lot to do with reality. When our students come back, their views are very much altered. For many, the experience helps them understand that stereotypes don't hold true for individuals. That's part of our intercultural training that we hope to impart to students."

That process cuts both ways, she says, because for some Latin Americans, WPI students help dispel the stereotype of the gringo from North America: "brash, loud, unknowing about other cultures and thinking the only place worthwhile is the United States. Stereotypes like that come from tourists who've seen inconveniences—or what they perceive as inconveniences—as negative aspects of another culture."

Vernon-Gerstenfeld's background in clinical psychology makes her keenly aware of the emotional impact immersion in a foreign culture can have. She talks to students about it before they go, while they're away and after they get back. "We want to teach students to ask themselves, 'What are you feeling; what are you acting on?,'" she says. "Instead of their colonizing and becoming defensive, we hope they'll explore the issues and then, perhaps, give up the colonizing."

She recalls one student who went to Ecuador and spent most of his free time watching television in his hotel room. As he began to realize that his television habit was a way of dealing with his discomfort with the culture, he relied on it less and less. "As we prepare these kids to go abroad, we need to teach them about the variety of feelings they may have and suggest strategies for handling the ones that make them uncomfortable."

After students return from a project site, they meet with the next set of teams scheduled to travel there. The returning teams discuss their experiences and offer tips on everything from how to use public transportation to how to do laundry. "I think it works," Vernon-Gerstenfeld says. "The vast majority of our kids end up being tremendously intrigued by what happens to them."

JANET WOODCOCK

Professor James Rollings directs WPI's project programs in Latin America. He's seen here with items from Ecuador, where he served as one of the first resident advisors of WPI's new Ecuador Project Center in Guayaquil.

James E. Rollings, associate professor of chemical engineering and director of the Latin American Project Program, is himself evidence of the transforming power of living and working in a culture other than one's own. Rollings, who has served as the resident faculty advisor at WPI's newest project center in Guayaquil, Ecuador, created in 1992 with a five-year, $500,000 grant from the U.S. Agency for International Development, joined the Peace Corps after getting his bachelor's degree in biochemistry. He taught chemistry and biology from 1972 to 1975 in Mombasa, Kenya.

When he returned to the states he earned a second bachelor's degree in chemical engineering before going to graduate school and studying for a doctorate in biochemical engineering. He'd come back from Africa with the thought that he wanted to make an impact on some of the social problems he'd seen while he was in the Peace Corps. He says WPI's project-based curriculum and the Global Perspective Program have enormous appeal to him as ways to combine his views about the importance of expanding cultural horizons with his work as a teacher and scientist.

Rollings says he believes that despite the useful work achieved through IQPs, MQPs and Humanities Sufficiencies done abroad, the greatest benefit is the way the Global Perspective Program changes WPI students. "In reality," he says, "by going away you'll make a greater change in your own society than you will in the society you visit. By providing students with that external moment, we're giving them a view of the world they would never have had except by leaving home and seeing how another culture functions.

"The culture shock is greater when you return than when you leave, because some of your assumptions may have been exposed. The experience of having been in another culture makes it possible to more clearly see—and perhaps question—one's own cultural assumptions."

Zeugner says he is "absolutely convinced that the most educational thing anybody can do is to sit in an alien culture for an extended period of time—not as a tourist, but as someone trying to function the way people in that culture function. That experience calls into question all your assumptions about how the world works. All the unconscious assessments you make to get through the day suddenly become conscious. I'm absolutely, passionately convinced that nothing else we do will have as profound an impact on students.

"Is that experience really worth it? From an educational point of view, absolutely. It will transform people and open them up. Studying the aftermath of a chemical explosion in a Bangkok slum is going to make someone a different kind of engineer. Somebody like that will understand that cultural assumptions have a terrific impact on the kinds of technological interactions that become the life circumstance of engineers. They're not going to think about them in the same way again."

The United Nations of WPI

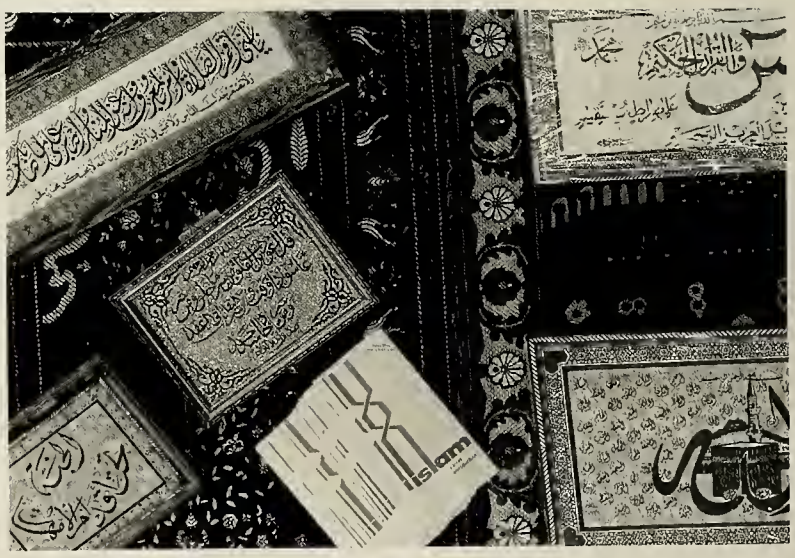
Through the Cultural Festival, the African Marketplace and a host of other events, students of many cultures and nationalities are bringing the world to WPI.

Photos by Janet Woodcock

THIS SPRING, THE LOWER WEDGE was filled with the sights and sounds of Africa, as the Institute enjoyed the first African Marketplace. The event, sponsored by the Black Student Union and the Black History Month Committee, brought a number of vendors to campus to display their wares and show off African artifacts, including crafts from Kenya supplied by a Worcester business, bottom, left.

The New York City dance and drum troupe "Message From Our Ancestors," opposite page and page 19, performed for an appreciative audience that included Lachelle R. Hatten '94, right. Yvonne V. Harrison, director of the Career Development Center, bottom, right, read a poem by Frances Ellen Watkins Harper, one of several readings during the day.

The Marketplace was just one of a host of events held on campus during the year by WPI's international students, who make up about 10 percent of the undergraduate student population and about half of the college's full-time graduate students, in concert with other students from a variety of backgrounds and cultures. The events



were designed to let the students share their traditions, crafts, cuisines and arts with the WPI and Greater Worcester communities.

A major annual event aimed at achieving that goal is the Cultural Festival, which observed its eighth anniversary this spring. Sponsored by WPI's International Student Council, the festival offers visitors the chance to sample arts, crafts and food from the cultures of WPI's international students. Performances and demonstrations, planned and mounted by the students themselves, run continuously on stage throughout the four-hour event.

At this year's festival, visitors were treated to Latin dances by a troupe that included Carlos A. Zapata '95, a native of Venezuela, and Leila J. Carvajal '96 from Ecuador, opposite. The dancers were members of the Hispanic Student Association. The Chinese Student Association purchased a 110-foot ceremonial dragon, top of page, which they paraded around Alden Memorial in a highlight of the festival. In China, the dragon dance is a traditional part of the New Year's festivities.

Students also shared dishes from their homelands, prepared by WPI's food service, and displayed crafts and artifacts from their cultures (see bottom photo, next page). These included an assortment of Islamic items provided by the Muslim Student Association, above. Richard H. Kim '95, in midair, next page, was part of a team that put on a demonstration of Tae Kwon Do, a form of Korean martial arts.

The annual festival is open to the entire Worcester community, and each year many students from Worcester-area schools stop by to enjoy the sights, sounds and tastes. A snowstorm kept most schoolchildren from enjoying the 1993 festival, but more than 1,500 students came in 1992. In 1991, the City Council declared the day of the Cultural Festival "International Student Day" in Worcester.

Outreach to the public schools has become an important mission of the Institute's international students. This year some 40 students visited Worcester public schools to talk about their cultures. Their efforts are part of a project called Globalizing the Curriculum, being undertaken by WPI and the Worcester School System. Funded in part by a U.S. Department of Education grant, the project seeks to help young students understand and appreciate other cultures.

Tom H. Thomsen, associate dean of student life and international student advisor, says he hopes WPI students can share many elements of their cultures with Worcester schoolchildren, as they did this year with the WPI community through a Chinese film series, an Asian Dinner that featured food from Indonesia, Korea, Thailand and Vietnam, and Hispanic Awareness Week, complete with a speaker, a band and movies.

Thomsen says these many activities are clear evidence that at WPI, globalization is a two-way street. He says that just as spending seven weeks in another country can broaden a student's horizons, interacting with students from other nations and backgrounds on campus can be a powerful and effective way to learn about other cultures.

"Living with an international roommate, for example," he says, "can be just as effective an introduction to another culture as traveling to an overseas project center. We want all students, including those who for whatever reason can't leave campus, to be able to say they have truly been exposed to people from other cultures before they graduate."

The Law of the Frontier

Once thought of as stodgy, patent law today is anything but. Patent attorneys are helping shape the leading edges of science and technology, trying cases where millions of dollars hang in the balance, and working to bring greater harmony to patent systems around the world. The best part? Opportunities abound for technically trained men and women.

BY MICHAEL W. DORSEY

It is, to be sure, a quiet revolution. But in law firms across the country, attorneys are noticing a striking trend. After decades of relative obscurity, the law of intellectual property —patents, copyrights, trademarks, trade secrets and unfair competition—is emerging as one of the hottest areas of legal practice. As a recent article in the *ABA Journal*, the magazine of the American Bar Association, put it, "Forget the trendy law practice areas of the 1980s, such as mergers and acquisitions, real estate and antitrust. Intellectual property is where the action will be in the 1990s."

If intellectual property is hot, patent law is truly incandescent. "A good demonstration of that is the fact that many of the major general law firms around the country are attempting to purchase or acquire smaller patent law firms," notes Paul N. Kokulis '45, senior partner at Cushman, Darby & Cushman, one of the largest intellectual property firms in Washington, D.C. "These firms all have real estate sections, banking sections, antitrust sections, environmental sections and so on. Now they want to have intellectual property sections, as well."

Kokulis, whose areas of expertise include biotechnology and biochemistry, says the explosive growth of new technology around the world is one factor in the renewed interest in patents and patent law. "In addition," he says, "of all the areas of legal practice, intellectual property is probably the most resistant to economic downturns. It's certainly not recession-proof, but in tough times, when corporations aren't doing as much research and development, they want to protect their existing business areas more vigorously. And that creates more activity in the patent field."

All this translates into growing opportunities for young lawyers in a field that has rarely—if ever—been oversaturated, notes Lawrence F. Scinto '51, partner with Fitzpatrick, Cella, Harper & Scinto in New York City, among the largest intellectual property firms in the nation. "This field is just beginning to realize its potential," he says. "With the growing demand by corporations for protection for their intellectual property and the rising awareness of the importance of intellectual property assets, people entering the profession today will find they are joining a truly growing field."

The American patent system, authorized by Article I of the U.S. Constitution, was the invention of Thomas Jefferson, who also served as the first commissioner of patents. As conceived by Jefferson and formally codified in the federal patent statutes (the first patent act was signed into law by George Washington in 1790), a patent is a legal monopoly granted to an inventor.

A patent gives an inventor the right to exclude others from using his or her invention for 17 years from the date the patent is granted. A patent holder can license the patented technology to others, who pay royalties for the privilege of using it. Patents can also be bought and sold like other personal property. Patent protection is designed to encourage the kind of innovation and technical progress that can benefit the nation as a whole.

Not every invention is patentable. The task of deciding what "process, machine, manufacture or composition of matter, or any new and useful improvements thereof," is worthy of patent protection falls to the more than 1,400 patent examiners who work in the modern facilities of the U.S. Patent and Trademark Office in Crystal City, Va. In making their decisions, they are guided by several key principles.

First and foremost, an invention must truly be new. Examiners will search through the millions of patents on file in Crystal City to make sure a patent has not already been granted for the invention. In addition, they'll want to be sure the device or process was not already in use or described in print before the inventor supposedly thought of it.

While it is possible to get a patent for an improvement on an existing device, process or composition of matter, if the examiner determines that the improvement would have been "obvious" to anyone skilled in the art to which the invention relates, the patent will be denied.

The invention must also be useful. In other words, the inventor must be able to demonstrate that what he or she has created has practical value. Finally, the examiners must decide if the inventor has adequately disclosed the details of the invention in a manner that will allow others skilled in the art of the field to reproduce it.

"The real reason for patents—the reason the government gives you this right to exclude—is that you are telling the world about your invention," says C. Marshall Dann '35, former U.S. commissioner of patents and trademarks who is now largely retired from the firm of Dann, Dorfman, Herrell and Skillman in Philadelphia. "Once your patent runs out, everyone else will be free to use it. So it's important that the invention be disclosed in a sound, technical manner."

While most of the early patents granted in the U.S. went to individual inventors, today a large share are owned by corporations. In fact, patents have become a cornerstone of our modern industrial society, since they help companies maintain a technical edge over their domestic and foreign competitors. Corporations are, of course, under no obligation to patent their inventions, and some decide instead to keep their technology trade secrets. But that route has its risks, Dann says.

"There aren't many things you can keep secret for long. You might be able to conceal some little process wrinkle. But if it's anything a competitor can tell from your product—or something he can discover independently—it's fair game. And employees move about a great deal today. Even if they don't intentionally steal your secrets, they can transmit a good deal of information to their new employers. And, of course, there's a certain amount of commercial espionage.

"If you have something good, you can keep it out of your competitor's hands by protecting it with a patent—assuming it's a good patent. Or you can make some money licensing it. The bottom line is that most companies simply can't afford to ignore patents."

"If you have something good, you can keep it out of your competitor's hands by protecting it with a patent.... The bottom line is that most companies simply can't afford to ignore patents."

Patent attorneys beginning their careers today will find a legal system far more friendly to their work than the system Dann, Kokulis, Scinto and most of the more than 40 WPI alumni who work as patent attorneys discovered when they entered the field.

In the 1930s, the tradition of protecting the rights of American inventors ran afoul of growing antitrust sentiment. "The Temporary National Economic Committee, a joint executive-legislative body established in 1938 to curb monopolies, made a lot of noise about corporate abuse of patents," Dann notes. "They started out to prove a preconceived notion and in the process painted the whole patent system pretty blackly."

According to Paul M. Craig Jr. '45, consulting attorney at Dow, Lohnes & Albertson in Washington, D.C., at least some of the antitrust fever was justified. "In the 1920s and 1930s, some companies were pooling patents to fix prices or to keep outsiders out," he says. "That helped give the patent system a bad name."

The anti-patent sentiment that emerged in the courts in the 1930s and 1940s persisted for decades and came to play an important role in how attorneys approached patent-related court cases, says Scinto, whose specialty is patent litigation. Until recently, patent cases were tried in 10 federal circuit courts that had disparate records on patent litigation. "Some circuits didn't hold a patent valid for 10 to 15 years," Scinto says. "Others were more hospitable. It was a common

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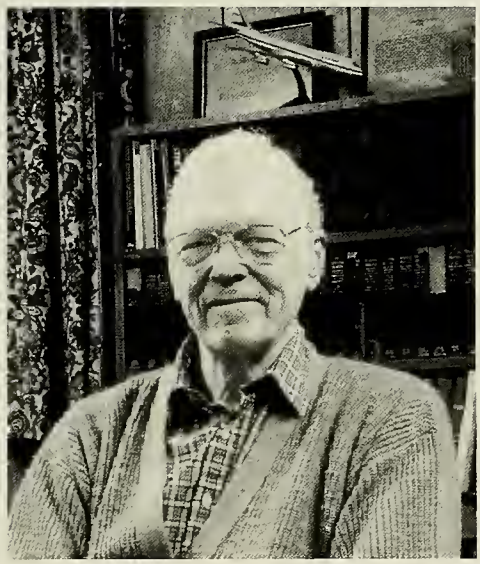
PATENT PROFILES

C. Marshall Dann '35



MICHAEL OORSEY

After he graduated from WPI in 1935 with his degree in chemistry, C. Marshall Dann settled down at DuPont for what seemed like the start of a long career in chemistry. But in 1945, Dann was assigned to a patent liaison group in DuPont's Pigments Department. "I thought patent law seemed like a pretty good field," he says. "I decided if I was going to be in it, I'd rather be all the way in rather than halfway."

For four years, Dann worked in DuPont's Washington, D.C., office as a patent agent while attending Georgetown University at night. In 1949, with his bachelor of laws degree in hand, he returned to the company's Wilmington, Del., headquarters as a patent attorney. One of his first assignments was to help out with a major antitrust case the federal government had filed against DuPont and Imperial Chemical Industries of Great Britain. (That case would also figure prominently in the start of Paul Kokulis' career as a patent attorney; see page 30.)

When the antitrust case was over, Dann worked on patent cases involving new organic chemicals, including polyurethanes, which were just then being introduced. In 1954, he was promoted to assistant manager of DuPont's Patent Department. At that time, Dann says, DuPont was filing about 800 patent applications a year and receiving about 500 new patents.

"During those years, I was concerned with patent matters across the board, rather than specific cases," he says. "But there were a few lawsuits I was directly involved in." In one case, DuPont sued Phillips Petroleum Co., alleging the corporation had infringed its patent for linear polyethylene, a plastic used in containers, electrical insulation and packaging. After three years, the case was settled out of court, with Phillips receiving a license to make the compound in return for financial and other considerations.

Dann was named DuPont's chief patent counsel in 1968. Six years later, after nearly 30 years with the company, he received a job offer. "I got a call from a gentleman who said, 'I'm from the White House,'" Dann says. "I sat up a little straighter. He said, 'Have you ever thought about taking early retirement and becoming commissioner of patents?'"

At first reluctant to leave Wilmington, Dann finally accepted. "I had been sitting in the same corner office for quite a number of years and a change began to seem attractive," he says. One of the major challenges he faced during his three years in Washington was resolving a conflict between the Commerce Department, which includes the Patent and Trademark Office, and the Justice Department over a proposed patent reform bill.

The bill, which grew out of a set of far-reaching recommendations of a Johnson administration commission on patent reform, was amended to include a troublesome provision that would have made it easier for corporations to avoid antitrust action when they granted licenses on their patents. "That had the effect of getting the Justice Department involved," Dann says.

Justice prepared its own reform bill that would have greatly complicated the process of prosecuting patents. "It seemed to me, as it did to a lot of other people, that the bill as it stood would have discouraged many inventors who wanted to protect their property," Dann says.

One of the duties of the commissioner of patents is to revise or expand the formal rules governing the operation of the Patent Office, as needed. Dann put in place new rules that incorporated the better parts of the Justice Department bill, but which were less burdensome to potential patentees. "Justice backed off and lost interest after that," Dann says. "The rules had the desired effect of stopping all the activity aimed at radically remaking the patent laws."

In 1977, after the election of Jimmy Carter, Dann joined the intellectual property firm of Dann, Dorfman, Herrell and Skillman in Philadelphia. Over the next 10 years he served as an expert witness in numerous interference and infringement cases around the country, including 45 that made it to the courtroom. "I testified about patent procedure and about the meaning of the claims in a patent," he says. "Claims define the patentee's right to exclude others, and they must always be interpreted by the court."

While he testified on behalf of all manner of plaintiffs and defendants—from major corporations like Dow, American Can, Pfizer and 3M, to individual inventors—one case was especially rewarding, Dann says. "An Illinois farmer named Billy Watkins had invented a device used in tractor-pull contests. It slowly increased the weight on the tractor as it pulled forward, so the tractor would eventually stop. He sued the National Tractor Pull Association, which had ignored his patent. He eventually won an injunction."

(Continued from Page 26)
tactic in those days to bring an action in a circuit you believed would look more favorably on patents."

In the early 1980s, alarmed at the apparent lack of uniformity of the country's patent system, which resulted in this so-called "forum-shopping," the U.S. Congress decided the time had come for change. "One thing that pushed Congress to act was concern about the trade deficit and foreign competition," Dann says. "Fifty years ago, 90 percent of all U.S. patents were obtained by U.S. citizens. Now it's about 50 percent. If you destroy the incentives for U.S. inventors to file patent applications, you're giving the competition an edge."

In 1982, Congress created the Court of Appeals for the Federal Circuit. Formed by combining the Court of Customs and Patent Appeals and the Court of Claims, the new body became the sole jurisdiction for appealing patent cases from any federal district court around the country. The Federal Circuit Court removed much of the preexisting regional anti-patent bias and "put a lot of vitality back into the patent system," Craig says.

While the new court has raised the value of patents in all industries, it's had a particularly profound effect on makers of computers, notes high-technology specialist William L. Anthony Jr. '61, a partner with Brobeck, Phleger & Harrison in Palo Alto, Calif. "Before the creation of the Federal Circuit Court, patents were virtually unenforceable in California, the home of a substantial portion of America's high-technology industry," he says.

Before 1982, Anthony notes, high-technology companies were more likely to license their technology for meager fees than to attempt to enforce their patents. And companies came to rely on trade secrets, rather than patents, to protect their inventions. Even so, technology moved relatively freely from company to company as engineers changed jobs or started their own firms. In fact, he notes, the explosive growth of the high-technology industry in the 1970s is attributable, in part, to "the peculiar mores of Silicon Valley (commonly referred to as 'piracy' in other parts of the world)."

Today, most high-technology companies have beefed up their patent departments and their patents are garnering respectable royalties. Companies like Texas Instruments and Motorola, which bucked the trend in the 1970s and stockpiled patents on their inventions, are now reaping the rewards of those higher royalties. In fact, insiders say, these and some other major companies now earn more from their patents than from sales of their products.

William L. Anthony '61, a partner with Brobeck, Phleger & Harrison in Palo Alto, has made a specialty of high-technology patent litigation.

"Fifty years ago, 90 percent of all U.S. patents were obtained by U.S. citizens. Now it's about 50 percent. If you destroy the incentive for U.S. inventors to file patent applications, you're giving the competition an edge."

People often think a patent gives them some property," Dann says. "But it really doesn't give them anything until a court says it's a good patent." The truth of that statement is illustrated by the marked increase in patent-related court cases that followed the creation of the Federal Circuit Court. In addition to increasing the value of patents—and the incentive to fight for them—the court raised the stakes in patent litigation.

When federal courts were as likely to rule a patent invalid as to sanction an infringer, corporations were less inhibited about helping themselves to patented technology. But the Federal Circuit Court is far more prone than earlier courts to come down hard on infringers, imposing damages and fees that make those levied by those earlier courts seem tame.

"At one time it was the norm for a damage recovery in a patent case to be limited to a reasonable royalty," Scinto

(Continued on Page 31)

Protecting Intellectual Property on Campus

With their mission to pursue and disseminate new knowledge, it's not surprising that colleges and universities have long been hotbeds of intellectual property. But it has only been in recent years that many research institutions have become aggressive about protecting the inventions and other creations of their faculty members and students and putting that property to use to generate revenue.

WPI developed its first intellectual property policy in the early 1970s. Among other things, the policy specifies when the Institute is entitled to the rights to patents, copyrights and trademarks for intellectual property created by its faculty and students and spells out how royalties generated by that property will be shared by the college and the inventors or authors.

During the last year, a committee of faculty members has been at work updating that policy. One of the key changes they plan to recommend will require the college to determine whether a faculty or student invention has commercial potential before deciding whether to pursue a patent for it.

"These days, with the competitive pressures of a global economy, it is often wise to apply for patents in several nations, not just in the U.S.," notes Kevin A. Clements, dean of graduate studies and research. "It costs a lot of money—perhaps $20,000 to $30,000—to go through that process. So we have to decide early on whether an invention is commercially viable and, therefore, worth patenting."

To help it make that decision, WPI recently joined with six other Worcester-area research institutions in creating the Unified Office of Technology Transfer at the Massachusetts Biotechnology Research Institute in Worcester. Heading that office is Skip Irving, whose jobs include helping the institutions identify commercially viable inventions, monitoring the process of patenting those inventions, brokering licensing agreements with companies and other partners, and providing assistance to faculty and students who may wish to license their own inventions from the Institute to start new companies.

Currently, WPI owns about a dozen patents and has applications pending on several more. Several other inventions are being evaluated, including at least a few that have been developed as part of undergraduate student projects. In fact, Irving says, one student project is now the subject of negotiations with a major medical products manufacturer and the prospects for licensing look good.

JANET WOODCOCK

Skip Irving of the Unified Office of Technology Transfer helps WPI decide what's worth patenting.

In addition to these, a few faculty members have patented their own inventions. At least one company has been founded based on faculty inventions and more are currently in the works.

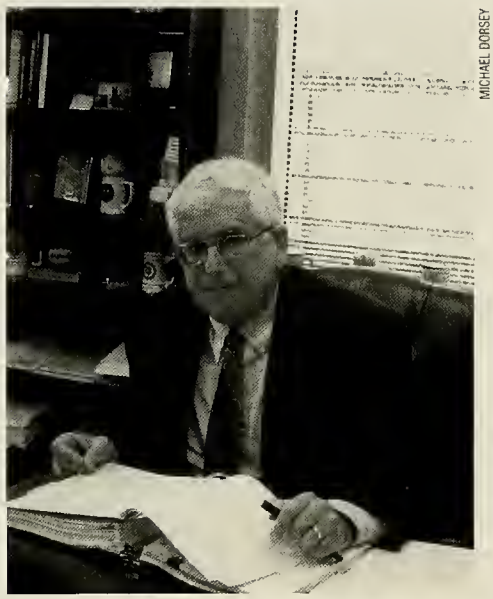
Irving says he hopes to see these numbers rise as more faculty and students become aware of the advantages of protecting their inventions. "There are some misconceptions we have to overcome," he says. "Some concern the conflict between patenting and publishing and how patenting fits into the mission and culture of an academic institution."

Irving says patenting and publishing should not be in conflict. With a little lead time, a U.S. patent can be applied for prior to publication, preserving the right to patent on a worldwide basis. "I want people to publish," he says. "That's my best advertising. That paper will be read by peers and by people at corporations. There's no conflict at all; in fact, the two should work in synergy."

Irving says that while the Institute will ultimately receive some income from its investment in intellectual property, the most important benefits will not be measured in dollars and cents. "For faculty members, patenting is an opportunity to get their research into the hands of people who can turn it into commercial products or processes," he says. "For students, it helps them develop an entrepreneurial spirit and teaches them something about the commercialization of technology. That experience will serve them well when they leave academia."

PATENT PROFILES

Paul N. Kokulis '45



MICHAEL DORSEY

Paul Kokulis has made a specialty of patent interferences, proceedings that seek to determine the rightful holder of a patent when two or more companies or individual inventors claim that right. "I would guess that most patent attorneys have one or two interferences in a lifetime," he says. "I juggle 15 to 20 such cases in a typical year."

Kokulis says patent law was the farthest thing from his mind when he received his degree in chemical engineering from WPI in 1944. He went to work for the Naval Research Laboratory as part of the Manhattan Project team, but left engineering after World War II. He left, in part, he says, because he felt other members of his research group, most of whom had advanced degrees, "were way ahead of me in their thinking. I didn't feel creative enough to make a contribution."

For a time he considered taking a job as a science teacher and a baseball and basketball coach in the Springfield, Mass., school system. But one day classmate Philip H. Sheridan, who is now a partner with Sheridan, Ross & McIntosh in Denver, urged him to apply for a post at the law firm of Cushman, Darby & Cushman in Washington, D.C., which was looking for someone with experience in chemistry.

"They offered me the position and paid my way through law school," says Kokulis, who earned his bachelor of laws degree at George Washington University by taking classes at night. "It was exactly what I needed. It has been a wonderful combination of science and the law. And it has allowed me to work with people at the frontiers of science."

Shortly after he joined the firm, a federal judge, in a major antitrust decision, ordered DuPont and the British company Imperial Chemical Industries (ICI) to terminate an agreement under which each company had filed for patents on the other's inventions in its own country. Faced with the need to pursue its own American patents, ICI turned to Cushman, Darby & Cushman.

"I was one of just two chemistry people at the firm then," Kokulis says. "One day an ICI man walked into my office with 400 pending patent applications, one or two appeals and some interferences. It was a wonderful opportunity for someone who was just beginning law school."

ICI has remained a principal client. In the 1950s, Kokulis worked with ICI and other companies on patents involving the highly competitive field of fibers and fabrics for clothing. He handled several interferences involving new reactive dyes, permanent press finishes and stretch fabrics.

The 1950s and 1960s also saw the growth of the pharmaceutical industry, and Kokulis found himself handling patents on major new drugs, including Halothane (an ICI invention that replaced ether as the anesthetic of choice in surgery), beta blockers (drugs used to treat angina and other heart ailments) and tamoxifen (the treatment of choice for breast cancer).

In the early 1980s, a significant amount of Kokulis' focus shifted to the emerging field of biotechnology. Today this discipline constitutes much of the work he does for clients that include major U.S. and foreign companies, universities and research institutions. The technologies he has been involved with range from blood growth factors to AIDS test kits to DNA fingerprinting.

"My involvement has been right there at the forefront of biochemistry," he says. "It's certainly been an exciting field to work in. If I were a young man starting out in patent law, I'd concentrate my efforts on this field, because there are some tremendously satisfying opportunities out there."

(Continued from Page 28)
says. "It was rare that a successful patentee could receive an award of lost profits. Of late, with more imagination going into damage calculations, awards are getting more significant and companies are looking at their patent portfolios as profit centers."

"Patent damage awards have become so substantial that many major corporations factor litigation-driven settlements and damages into their revenue projections as if they were expected income," Anthony says. "Texas Instruments, for example, has generated more than $600 million in royalties in recent years as a result of zealous patent litigation."

Anthony notes that the Federal Circuit Court is also more likely to invoke a provision for granting treble damages in cases where a defendant knowingly infringes a patent. All this has resulted in some staggering awards: $56 million for an antibiotic patent in Pfizer v. International Rectifier; $125 million for a patented cookie recipe in Procter & Gamble v. Nabisco; and $205 million for a patent covering the design of a rock drill bit in Smith Industries v. Hughes Tools.

In the most celebrated outcome, a judge awarded Polaroid more than $900 million after ruling that Kodak had infringed its instant photography patents. But Anthony says a new precedent may be in the wings: in a current case, Hughes Aircraft Co. is accusing the U.S. government of infringing its patents for satellite attitude-control systems. "Hughes has requested $3.3 billion," he says. "It is considered by many to be a reasonable estimate."

While most companies can absorb "reasonable royalties" into their bottom lines, the consequences of today's larger damage awards can be more severe. "Companies are being put out of business," Dann says. "That's why any company in any business where there might be inventions must pay attention to patents. Not only is it important to protect their own intellectual property, but they better make sure what they're doing doesn't infringe someone else's patents."

While the change in the judicial landscape has made corporations more cautious—and emboldened individual inventors, who in the past might not have taken on large corporate infringers—the escalating costs of bringing a patent case to trial can still tip the balance in favor of larger companies, Craig says. "Litigation has become terribly expensive," he says. "We are pricing it out of the reach of most individual Americans."

Last year, the firm of Morrison & Foster estimated that a patent trial can easily cost between $1 million and $4 million. "It can take $50,000 to $100,000 just to get a case on file," Craig notes. "More and more, small companies just can't afford to enforce their patents. And because litigation costs are deductible, the company with the deepest pockets has an advantage that enhances its chances of prevailing."

"More and more, small companies just can't afford to enforce their patents. And because litigation costs are deductible, the company with the deepest pockets has an advantage that enhances its chances of prevailing."

With so much at stake, strategy has become critical in patent litigation. One key strategic decision that must be made early on is whether to bring a case before a judge or a jury, Scinto says. "When I started in patent litigation, attorneys were more likely to try cases before the court, rather than a jury. There is an active trend today for exercising the constitutional right to a jury trial.

"Patentees often feel that juries will be more favorably inclined to a patent that has survived the scrutiny of a government review than to a challenger who says everything in the patent was obvious from the prior art." In addition, individual inventors involved in actions with corporations often choose juries because they feel jurors will be more likely to feel empathy with the little guy, Craig says.

"Patent litigators discovered juries about 10 years ago," Anthony says. "While the early indications of a jury's propensity to hold patents valid were impressive (with about 80 percent of patents being upheld), it appears over the long term that juries are not quite as much of a blessing to patent owners, but they're a blessing nonetheless."

In fact, Anthony says, judges are nearly as likely as juries to uphold patents. That's an important consideration, given the fact that jury trials are more expensive, time-consuming and difficult to schedule than non-jury trials. "The demand for a jury should not be a knee-jerk reaction of patent plaintiffs," he says.

Regardless of whether a case goes before a judge or a jury, the complexity of the issues involved in patent disputes, the intricacies of modern technology, and the increasingly crowded federal dockets (which may make judges less generous with the time they allow attorneys to present their cases) place a premium on preparation. "Preparation is the key in any kind of litigation," Craig says. "You can't leave a stone unturned."

An important part of preparing is finding the most effective way to present the details of a patent case. More and more, that means using television, computers and other modern communication technologies, Scinto says. "You make your case in a more rapid fashion, but you use computer animation, simulation—that sort of thing—to distill it down and make it understandable to the judge, who may have no technical training, and to the jurors, who may have no education beyond high school."

"Effective trial aids will not convert bad facts into good facts," Anthony adds. "But they can tip the balance in close cases. And by removing the cloud of confusion from a high-technology case, you demonstrate that you are doing your

best to impart an understanding of the facts to the judge or jury."

Two "clouds of confusion" that often surround patent suits are the issue of obviousness and something called the doctrine of equivalents, Scinto says. "Sometimes you can avoid the literal language of the claims of a patent and end up with the same results," he says.

"But the Supreme Court says that if you've reached that result by doing substantially the same thing in substantially the same way, you have not really avoided the patent and are guilty of infringement. That issue is the subject of a great deal of litigation."

Defendants in patent suits often claim that the patent in question is invalid because the invention would have been obvious to others skilled in the prior art. "Sometimes, you can arrive at a pretty reasoned opinion as to whether something was obvious, but often it will depend on the nature of the evidence produced at the trial, and you never know what that will be in advance. In the end, you are relying on the experience and knowledge of the person rendering the opinion."

> *"Sometimes you can avoid the literal language of the claims of a patent and end up with the same results.... That is the subject of a great deal of litigation."*

If I were advising young people considerng careers in patent law about what fields to get preparation in, I'd say computers, semiconductor technologies, bioengineering, biotechnology and genetic engineering," Craig says. In fact, the computer and biotechnology industries have proven hotbeds of patent activity in recent decades.

Makers of computer software have traditionally turned to copyright law to protect their products (copyrights protect expressions of ideas—like books, plays and musical scores—rather than the ideas themselves), but patents have been granted to fundamental advances in software design. Patents are, perhaps, more critical for advances in computer technology, where such fundamental advances as the integrated circuit and memory design can be worth billions of dollars in royalties.

The rapidly changing nature of computer technology has given rise to a myth that patents—which can take several years to be granted once an application is filed—are not worth pursuing when a new chip might be obsolete a year or two after it goes on the market.

"In truth," Anthony says, "basic technologies are retained, albeit in a much improved form, as a product evolves into more advanced designs. For example, a patent basic to a dynamic random access memory (DRAM) disclosed in a one-kilobyte context, may be equally applicable to a one-megabyte design."

The explosion of patent work in biotechnology can be traced to the invention of genetic engineering in the early 1970s and to a pivotal Supreme Court decision in 1980. In Diamond v. Chakrabarty, the court ruled for the first time that manmade microorganisms can be patented. Later court rulings extended that protection to genetically engineered plants and multicellular animals, and patents have also been granted for individual genes and proteins—both natural and manmade.

Patents have proven especially important in biotechnology for a number of reasons. One of the most compelling is the high cost of the research, development and testing needed to bring a genetically engineered product to market. In 1991, biotech companies spent $3.2 billion on R&D—an average of 47 percent of their incomes. Pharmaceutical companies, in contrast, spend about 15 percent of their incomes on research and development.

If that investment were not enough reason for protecting biological and biochemical inventions with patents, the relative ease with which such inventions can be copied or "reinvented" should be. For example, once a company has begun clinical trials for a new genetically engineered protein, a competitor may find it easy to get a sample of the compound, analyze it, and determine the sequence of the gene needed to make it.

But outright piracy is only one of many ways a company can try to wrest control of a new market from its competitors or steer around its rivals' patents in the brave new world of biotechnology. Kokulis has been involved in some of the most written-about and closely studied interference cases in this emerging and challenging field.

Some of those cases concern Amgen Inc. in Thousand Oaks, Calif., one of the world's largest biotechnology companies. Amgen has focused much of its efforts on a group of biological compounds called blood cell growth factors, chemicals made by the body that stimulate the growth of the various cells that constitute human blood. One of its first targets was erythropoietin (EPO), which boosts the production of red blood cells. The compound can benefit patients on kidney dialysis, who often suffer from anemia brought on by the destruction of red blood cells.

EPO is produced by the kidneys in very small amounts, but isolating enough of the natural compound for commercial production would be prohibitively expensive. Therefore, Amgen and other companies—most notably, Genetics Institute in Cambridge, Mass.—set out to isolate the gene that codes for the protein. It was an arduous search; at times, both companies came close to giving it up. But in the end, Fu-Kuen Lin at Amgen isolated the gene and Amgen obtained patents for it and a host cell for manufacturing EPO using the isolated gene.

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PATENT PROFILES

Paul M. Craig '45

Paul Craig, a German native, arrived in the U.S. as a young man and entered WPI as a classified freshman with the Class of 1945. Due to a lack of a deferment, he had to interrupt his studies during his senior year. He served in the U.S. Navy from 1944 to 1946 and returned to WPI to complete his bachelor's degree in electrical engineering a short time later.

His entry into the field of patent law, he says, was purely accidental. "I was invited by RCA to come to Camden, N.J., for a job interview in the fall of 1946. On the advice of a neighbor, who worked with a Worcester patent law firm, I extended my trip so I could visit Washington. I was immediately hired as a patent examiner in an electrical division of the U.S. Patent Office."

Craig started work in December 1946 and enrolled at Georgetown University to work toward his law degree at night. After receiving his bachelor of laws degree in 1950, he became a patent advisor for the U.S. Army's Office of Chief of Ordnance. "All of the Army's arsenals reported to that office," Craig says. "Some of the work I handled came from the Redstone Arsenal, where German scientists under Wernher von Braun were working on rocket technology. I handled claims, filed patent applications and worked on infringements."

While working for the Army, Craig earned a master's degree in law at George Washington University. He left the Army in 1952 and went into private practice, where his knowledge of foreign languages would prove to be a major asset with future European clients.

While most of the work he did over the next several decades was in his area of specialization, patent litigation, he spent a good part of the 1950s and 1960s in general law practice with his father, also Paul Craig (both Paul Craigs were admitted to the bar on the same day in 1950).

In 1983, he split off from the Washington, D.C., intellectual property firm of Craig & Antonelli, which he had founded, and started the firm of Craig & Burns. Three years later that firm merged with a law firm in Indiana. "The Indiana firm had a policy that required partners to retire at 67," he says. "I was worried that the policy might keep me from continuing to serve a longstanding client who insisted on my representation, so I left the firm in January 1989 and since then have been associated with Dow, Lohnes & Albertson, a large general practice law firm in Washington."

When Craig began his patent law practice in the 1950s, the leading-edge technologies included nuclear energy and electronics. In the electronics area, corporations were working to develop and commercialize technologies developed during World War II. In his last year at the Patent Office, he became involved in major interferences that involved all the major U.S. firms that had access to the MIT Radiation Laboratory in a fight for the rights to an important development in radar, the "Magic T" antenna, which could send and receive microwave signals.

Over the years, he has done a great deal of work for electronics and automobile manufacturers. He has handled a broad range of work in the intellectual property area, including litigation, for European automotive clients such as Damiler-Benz, BMW and Porsche, and several Japanese companies, including Hitachi. He was involved for more than a decade in the Kearns litigation, in which David Kearns sued many automakers for alleged infringement of his intermittent windshield wiper patents.

Craig says he has enjoyed his career in patent law, but he notes that the profession has its pluses and minuses. On the plus side are salaries that are generally higher than those most engineers or research scientists can expect, as well as the opportunity to use one's technical education in an exciting and creative field, he says.

"But this is also a time-consuming and time-demanding profession," he says. "That can be a detriment. I remember when my daughter was 12, I asked her what she wanted to be when she grew up. She said she wasn't sure, but she knew she wasn't going to be a lawyer, because she wanted to spend time with her kids."

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In theory, that should have concluded the race, but Genetics Institute had a surprise in store for Amgen. Just before the awarding of Amgen's patent, GI had obtained a patent for a purified sample of EPO the company isolated from human urine. Genetics Institute argued that its patent also covered the synthetic form of EPO Amgen planned to make with its patented gene and process.

A lower court agreed with GI, but the decision was overturned on appeal to the Federal Circuit Court. Both the lower court and the appeals court found Amgen's patent valid and infringed by GI. Kokulis says the story of EPO also involved several interferences (special proceedings to determine who was the first inventor of something, and therefore the rightful patent holder) over Amgen's gene and process.

The interferences, in which Kokulis was involved, were determined favorably to Amgen by the U.S. Patent Office, although appeals are pending. An important ruling in the litigation and the interferences, Kokulis says, is the finding that, with gene inventions, conception of the invention and its reduction to practice occur simultaneously.

Kokulis says there is an important weakness in current patent coverage for biotechnology. "To illustrate this," he says, "let's say you are the first to isolate the gene for a protein that exists naturally in the body and that has been known about for some time. The protein is old, but your method for making it is new and you get a patent in the U.S. on the gene, and not on the protein it codes for.

"A company in Japan uses your gene to make the protein and then exports it to the U.S. As things stand now, that company will have no infringement problems, because it has not used your gene in the U.S. And since you hold no patent on the protein itself, it can be exported to this country.

"An apparently easy answer to the problem is to obtain patent coverage for the process for making the protein using the gene, since current law specifies that the importation of a product made by a process that would infringe a U.S. patent if made in the U.S., is itself infringement. But such process coverage is not always available."

That was the issue at the heart of litigation filed a few years ago by Amgen against Chugai Pharmaceutical, a major Japanese biotechnology company. Before the award of the Amgen gene patent, Genetics Institute had given Chugai the gene and host cell needed to make EPO and entered into a joint venture with the Japanese company to sell the protein in the U.S. Amgen protested the arrangement to the U.S. Trade Commission, but lost. "There have been proposals for legislation that would remedy this type of situation," Kokulis says, "but to date none have passed."

Perhaps the most publicized interference Kokulis has been involved in concerned the isolation of the virus that causes AIDS and the development of the first AIDS test kit. The case pitted Robert Gallo, discoverer of interleukin-2 and the first human retrovirus, HTLV-1, against French virologist Luc Montagnier and the Pasteur Institute.

In 1983, while Gallo's lab raced with the French lab to be the first to find the virus responsible for AIDS, Montagnier sent Gallo a sample of LAV, which he believed to be the culprit. A short time later, Gallo announced the isolation of what he called HTLV-III, as well as an AIDS test kit based upon it. The NIH was later granted a patent for the kit.

Montagnier claimed HTLV-III was really the Pasteur Institute's LAV and charged misconduct in the creation of the test kit. The institute, in the meantime, had developed its own test kit and an interference was begun to determine which one deserved the right to patent protection. After numerous meetings in Washington and Paris, a settlement was reached.

> *"The interference....was to determine who developed the [AIDS] test kit first. As far as I am concerned, Gallo and his people were the first to do that, as they discovered the way to produce enough of the virus to make useful kits."*

"Both sides agreed that they had benefited from information the other had shared with them," says Kokulis, who was asked by the federal government to handle the Gallo case in what was seen as an unusual move (the Justice Department normally defends the government in interferences, he says). "In a settlement disclosed in a historic announcement in Washington by the presidents of France and the U.S., Gallo and Montagnier agreed that they were joint inventors of the test kit.

"The newspapers tended to overlook an important point in that case," Kokulis adds. "The interference was not about who isolated the virus first. It was to determine who developed the test kit first. As far as I am concerned, Gallo and his people were the first to do that, particularly as they discovered the way to produce enough of the virus to make useful kits. To do that they had to find an immortallized cell line that the virus would not kill. That was a great contribution."

Since the Gallo case, Kokulis and his firm have handled a number of patent-related cases for the NIH. One in particular has been the subject of controversy. That case began in August 1992 when the agency filed for patents on the research of former NIH scientist J. Craig Venter. Venter isolated more than 3,000 partial human genes known as expressed-sequence tags. The sequences can be used as probes to isolate the exact position of useful genes. The NIH says it wants to secure the intellectual property rights to the sequences so they will be available to anyone who needs them for research.

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PATENT PROFILES

Lawrence F. Scinto '51

Like many patent attorneys, Lawrence Scinto didn't set out to pursue a career in law. A native of New York City, he enrolled at Brooklyn Polytechnic Institute after high school, and then served in the U.S. Army in the Pacific Theater for two years at the end of World War II.

"When I got out of the service, I decided to take advantage of the G.I. Bill and began looking for a college outside of New York," Scinto says. "I had relatives in Worcester who told me about WPI." Scinto was admitted and earned a bachelor's degree in civil engineering in 1951.

In his senior year, he took a course in engineering and the law and became intrigued. When he returned to New York, he enrolled at St. John's University and pursued a bachelor of laws degree at night while working at various engineering jobs during the day. He received his degree in 1956 and went on to earn a master's degree in law at New York University in 1959.

Still, he didn't intend to work as a patent attorney; he says he thought a knowledge of the legal field would be helpful in his work as an engineer. But after spending a year as a contract administrator at an engineering firm, he took a job as a patent attorney for American Machine and Foundry Co. and has never looked back.

For American Machine, he prosecuted patents on technology used in such devices as bowling pin-spotting machines, cigarette-making and -packaging machines, and bread-wrapping machinery. In 1960 he joined the New York firm of Morgan, Finnegan, Durham & Pine. Three years later he joined Ward, Haselton, McElhannon, Orme, Brooks & Fitzpatrick, where he eventually became a partner.

In 1971, he joined with other attorneys in forming Fitzpatrick, Cella, Harper & Scinto, where he is a senior partner today. With 65 attorneys in the main office on Park Avenue, another 22 in an office in Washington, D.C., and three lawyers in a Los Angeles office, the firm is one of the largest intellectual property practices in the country.

Over the years, Scinto, who was recently elected to membership in the American College of Trial Lawyers, has focused more and more of his energies on patent litigation, which he has pursued for such clients as Exxon, DuPont, Merck, Monsanto, S.C. Johnson & Son, and Emerson Electric. The cases he has handled have run the gamut of technical disciplines and industries.

Early in his career, he worked on cases involving the high-speed manufacture of replacement radiator hoses for cars. He brought suit for DuPont against Hercules Chemical Co. over a patent for the photosensitive material used in making printed circuit boards. And he successfully defended Merck in a suit over its patents for crystalline and highly refined forms of vitamin B_{12}.

More recently, he worked on a case for DuPont and its licensees involving a patent for a plastic material used to make the expandable balloons for aortic catheters. Also working for DuPont, he was able to prove that a patent granted to another manufacturer for the use of the space-age plastic Kevlar in brake linings was invalid because previous DuPont publications already covered that application. Currently in litigation is a case that pits client Emerson Electric against General Electric in a fight dealing with brushless permanent-magnet motors.

"Everyday it's something new," says Scinto, who notes that working as a patent attorney has dispelled a myth he once had about the field. "I had the misconception that patent law was a very dull, stodgy area of legal practice. I could not have been more wrong. To me, it's among the most exciting and challenging areas. It's not always exciting, of course, but by and large it's the kind of thing I look forward to coming to work for every day."

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While the agency says it will be willing to transfer the rights to these sequences to biotechnology companies that can put them to good use, those same companies fear that granting the NIH patents on the gene segments will make it harder for them to get patents on the full genes, since knowledge of the sequences may make the genes obvious. "It will be interesting to see what the future holds for patenting efforts of this type," Kokulis says.

If there was only one patent system in the world, life—while not easy—would be a great deal simpler for patent attorneys. In fact, nearly every nation maintains its own patent system and within those many systems are a host of conflicting requirements and rules.

As global competition in business and industry has intensified in recent decades, the need for companies and individual inventors to protect their intellectual property outside of their home countries has grown. One indication of this is the changing nature of the clientele of the U.S. Patent Office.

"Foreign companies are getting about one of every two patents granted by our patent office today," Scinto notes. "In 1992, four of the top five companies getting patents issued in their names were non-U.S. firms. The Japanese, in particular, are quite sophisticated about using, not only our system, but patent systems around the world."

With the growth of international patenting, has come a rising interest in "harmonizing" the rules governing the many national patent offices. The goal is to make the process of applying for patents in multiple countries easier and fairer. In the long term, such efforts may someday bring about a truly international patent, which would provide access to patent protection in many—if not all—countries with a single application.

An important step along this road was taken more than a century ago when a number of countries signed the Paris Convention for the Protection of Industrial Property. About 100 nations now adhere to the Paris Convention, which requires a signatory country to treat applicants from other countries exactly as it does those within its own borders. It also grants inventors one full year from the time they first file an application in any member country to file applications in other nations. During that year, the inventor can preserve his right of priority, should priority of invention become an issue.

Students Pursue Patent Careers and Projects

While the majority of WPI's graduates go on to careers in the disciplines in which they major, a growing number are using their engineering and science degrees as stepping-stones to other types of professional occupations. Each year, about six of those students go on to study law, according to Kent J. Rissmiller, assistant professor of social science and policy studies and one of two advisors for WPI's pre-law program.

"For the first time this year, most of those students are interested in patent law," Rissmiller says. "They are selecting law schools because of their patent law programs and expect that the field is the best way for them to combine their education in engineering or science and their interest in law.

"I think it shows, in part, that students are a little nervous about the availability of engineering jobs and about what kinds of jobs they'll be qualified for if they have only a bachelor's degree. They don't want to ignore or set aside their four years at WPI; they just want to find other ways to use that education."

Rissmiller says students with a technical background often have an advantage in applying to graduate programs that specialize in technical areas of law, like the law of intellectual property, utility regulation and the environment. "In general," he says, "I tell students that having an engineering or science degree is no handicap whatsoever in getting into law school. These schools don't put a lot of weight on an applicant's major. They're looking for someone who can handle graduate education."

Through WPI's pre-law program, students receive special advising about career opportunities, preparing for law school exams, and applying to law school. In addition, students can take a sequence of law courses in the areas of management, history and social science.

"These courses expose students to the kinds of problems, the kinds of cases, and the kinds of materials they will encounter as law students," Rissmiller says. "We want them to see if they find it interesting and if they can adapt to learning through the case format used in law courses."

Patent law has also played an important role in WPI's undergraduate project program. For nearly two decades, students have been completing Interactive Qualifying Projects (IQPs) with the U.S. Patent and Trademark Office while in residence at the Institute's Washington, D.C., Project Center.

The relationship with the Patent Office began in 1974 with the assistance of C. Marshall Dann '35, who was then commissioner of patents and trademarks. It has continued since then, making it WPI's longest relationship with an off-campus project sponsor. Over the years, more than 20 projects have been completed with the office.

The projects have focused on such areas as the classification system used by the Patent Office and the use of modern automation technology in patent searches and other patent-related functions. Many have used data about patenting activity to learn about

There are currently a few regional patent offices that enable inventors to file a single application and be granted patents in multiple countries. The European Patent Office covers 14 nations on that continent. Other such arrangements cover the English- and French-speaking nations of Africa and the Benelux nations.

In the early 1980s, a movement began to bring even greater uniformity to the international patent community. Since then, the World Intellectual Property Organization (WIPO), a special agency of the United Nations, has drafted a treaty aimed at harmonizing international patent procedures. Marshall Dann, who attended meetings of the WIPO when he was U.S. patent commissioner in the 1970s, says that if the U.S. is to ultimately sign this treaty (as several nations have already done), it will have to make a fundamental change in its patent system.

> *"The U.S. will have to abandon the first-to-invent rule sooner or later."*

"Everywhere else in the world, with the exception of the Philippines, they have a first-to-file system," he says. "We've stayed with our first-to-invent system." A first-to-file system grants a patent to the first inventor to get his application into the patent office. The U.S. system is careful to award a patent to the first person to actually realize a new technology.

"There are virtues to a first-to-invent system," Dann says. "Because he doesn't have to worry about somebody stealing his idea, an inventor has time to develop and perfect it before running to the patent office. In theory, that results in higher quality patents.

"The great virtue of the first-to-file system is its simplicity. It also eliminates the need for interferences, which can be burdensome. One key argument against the system is that it might encourage sloppy and incomplete patent applications, which could result in more rejections and more vulnerable patents."

Dann says a first-to-file system may also favor large companies, which have the resources to file patent applications quickly. He says because most large U.S. companies patent their inventions overseas, they already operate as if the U.S. had a first-to-file system.

the process of creating and using new technology in the U.S. and about the social and economic implications of technology.

Jane Meyers, the Institute's primary contact in the Patent Office, says one project that particularly impressed her examined the impact of maintenance fees on patent holders. The fees, first assessed in the early 1980s, must be paid by inventors every four years to keep a patent valid.

"This project alerted us to the fact that we weren't notifying inventors adequately about the fact that these maintenance fees were due," she says. "As a result, the office instituted new procedures to notify inventors. We took the students' report, condensed it and published it. We distributed that publication to a lot of people."

A 1985 project looked at how placing the Patent Office's vast collection of patents on CD ROM affected the way people use those patents to do searches. The project was advised by Susan Vernon-Gerstenfeld, adjunct associate professor and director of the Washington Project Center. She used the data the students gathered under her direction to complete a Ph.D. dissertation that predicted how comfortable Patent Office employees would be adopting the new technology. "The male patent examiners who had been there the longest were the most reluctant users," she says.

"Projects like these can be of real value to the Patent Office," Vernon-Gerstenfeld says. "They don't have enough personnel to do this work or enough resources. So sponsoring a project is a good way to get a lot of talented labor. And our track record with them is very good, or they wouldn't have kept coming back for nearly 20 years."

That assessment is confirmed by Meyers: "The students have often planted seeds for further research on our part and in many cases we have followed through. I've got all the reports here in my office and we do use them—even the ones with older data—for reference."

When WPI opened the London Project Center in 1985, the Institute's track record with the U.S. Patent Office opened the door to the British Patent Office, where projects have been conducted regularly since then. Later, the British connection would help lay the groundwork for a series of projects with the Office of Registrar General in Hong Kong, which is responsible for all areas of commercial law on the island.

In Britain, many patent-related projects have focused on the satisfaction users feel with the services they receive from the British Patent Office. "The patent office perceived the enormous value of having WPI students, who are disarming and nonthreatening, gathering impartial responses from users," says Lance Schachterle, associate dean of undergraduate studies and director of the London Project Center.

The first project done with the British office looked at whether the creation of the European Patent Office might make the services of the British office obsolete. "The students came up with what we were told was a better, more accurate report than one the patent office had commissioned from a professional consulting firm," Schachterle says.

The report found that many British inventors would prefer to use their own patent office over the European office because it offers the services they need at a lower cost. "The patent search arm of the British Patent Office had thought it might go out of business," Schachterle says. "The students' report convinced them they had a future."

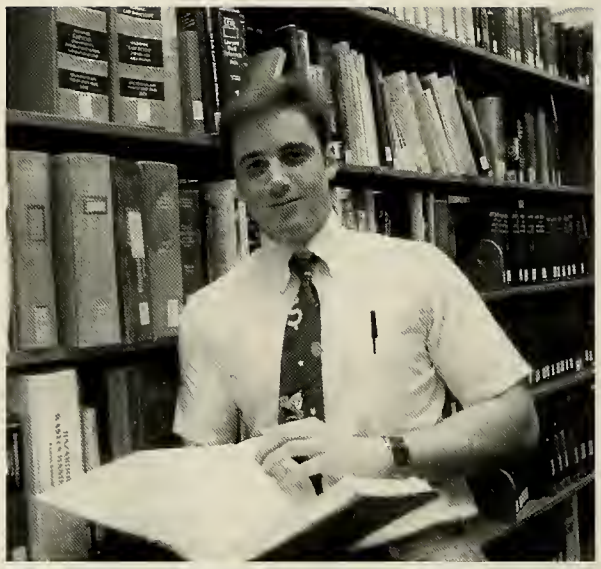
Morgan D. Rosenberg '95 has been looking into these questions for his Interactive Qualifying Project, which will examine how the transition to a first-to-file system might affect inventors in the U.S. He says he has concluded from his research that many of the fears about first-to-file may be unfounded.

"People who are for the first-to-file system say that while, in theory, small inventors could be hurt, it doesn't seem to happen in the real world," he notes. "And the level of quality of patents really depends on what individual countries require in the way of disclosure, rather than on whether or not they have a first-to-file system. Right now the U.S. has the strictest level of disclosure requirements of any country. If we switch to a first-to-file system, we'd probably retain those."

"The U.S. will have to abandon the first-to-invent rule sooner or later," Craig says. But he notes that many nations are more concerned about other provisions in U.S. law they consider discriminatory. "For example," he notes, "the patent system now favors U.S. inventors, because you cannot establish the date of your invention by activities abroad, such as conception of the invention or reduction to practice."

"Some say this gives U.S. companies a big advantage in interferences," Dann says. "It's true that we say that our law treats everybody the same—if you develop something in the U.S., you are on a par with us. That sticks in the craw of foreign companies.

"I don't know how the U.S. is going to come out on this," Dann adds. "There are a great many people—including, I think, the current administration—who favor the U.S. becoming like everybody else. A great many other people cherish the first-to-invent system. They note that the U.S. will get little in return for giving it up. We'll just have to wait and see."



MICHAEL DORSEY

Morgan Rosenberg '95 says his research for an IQP on patent harmonization convinced him that many objections to the first-to-file system are unfounded.

Patent law is an interesting field," Dann says. "It's a nice combination of law and technology. You can use what you know of science and engineering and you'll always find yourself at the leading edge of technology, because every application that you get into is, by definition, new."

How does a young man or woman get into the field? To begin with, Kokulis says, a technical degree is a must, because of the complex nature of the material a patent attorney must deal with. "All but a few of the people in our firm have a scientific background, and many started out by working in a scientific area," he says. "The few who do not have technical degrees work in trademarks and copyrights."

Once a prospective attorney has earned a law degree, what is the next step? "There are three common ways to break into the field," Craig says. "You can go to work for the Patent Office as a patent examiner and attend law school at night. This way you learn the rules and the thinking of the Patent Office, which is valuable. You can work for a firm. In Washington, people are hired right out of college; they do searches at first while they earn their law degrees at night.

"Or you can work for a company, especially one that has a Washington office for training patent attorneys. To take advantage of the opportunity to choose from among a wider range of law schools, however, companies are cutting back on their Washington training offices."

Each option has advantages and disadvantages, Kokulis says. "At the Patent Office you'll gain a lot of experience quickly and probably have more responsibility. At a firm you'll progress more slowly, but you'll have greater variety in the work you do. At a corporation you'll have a narrower exposure, because your cases will concern whatever technology the company specializes in."

Craig says there is a fourth alternative not often considered—serving as a clerk to a judge, especially a judge of the U.S. Court of Appeals for the Federal Circuit. "This will give you exposure to all sorts of cases," he says. "Many law firms pay a premium for attorneys who have had such experience."

What are the prospects for a new patent attorney? Currently, the demand for young men and women in this field is so great many firms are "growing" their own patent attorneys, the *Boston Globe* recently reported. One Boston firm is sending engineers to law school at its own expense.

New patent attorneys will join a small but growing fraternity. According to the American Intellectual Property Law Association, there are about 12,000 intellectual property lawyers in the U.S.—fewer than 2 percent of all attorneys listed by the American Bar Association. Those professionals might find they have an important advantage over their peers, Kokulis notes.

"Young people ask me about the practice of law," he says. "I tell them that if you go into criminal law, you'll probably get rather disenchanted with human nature. And I can see how one might find domestic relations law, where you are constantly confronted with people in turmoil, a bit depressing. But patent law mostly has ups. You are dealing with people who are out there making new inventions that, hopefully, will contribute to everybody's well-being and happiness."

Playing Matchmaker to Methane

JANET WOODCOCK

From left, William Moser, Anthony Dixon and Yi Hua Ma are developing an inorganic membrane system to convert methane into ethylene.

Sometimes called marsh gas or fire-damp, methane constitutes about 85 percent of natural gas and is also produced by the decomposition of organic matter. In addition to its use as a fuel, methane has long been an important starting point in a host of commercially important chemical processes.

In the petrochemical industry, for example, methane is often used to make synthesis gas (carbon monoxide and hydrogen), which is used, in turn, in the manufacture of methanol and ammonia. Since methane is abundant and cheap, a major goal of the industry is to find a way to convert methane to ethylene, a chemical building block used to make ethylene glycol, polyvinyl chloride, styrene, polyethylene, fabric finishes, latex paints and a host of other products.

To make ethylene in this way, two molecules of methane must be combined in a process known as oxidative dimerization. In practice, this is a difficult process to control and produces poor yields, generally in the range of just 25 to 30 percent, says Yi Hua Ma, professor of chemical engineering and director of WPI's Center for Inorganic Membrane Studies.

"It is not easy to put two methane molecules together," Ma says, "since methane does not readily react with itself. To make the reaction work, you must control the oxidation of the methane. When you burn methane, you completely oxidize it, producing carbon dioxide and water. But in the dimerization reaction, you partially oxidize the methane molecules, producing some carbon dioxide and water and some useful products."

With a three-year contract for $690,590 from the U.S. Department of Energy, Ma and chemical engineering professors Anthony G. Dixon and William R. Moser are attempting to develop an inorganic membrane system that will significantly increase the yield of the dimerization reaction by both controlling the rate at which oxygen mixes with the methane and promoting the coupling of the methane molecules.

Inorganic membranes are generally made by building up increasingly fine layers of inorganic materials like alumina, zirconia and glass. The finest layers have a uniform network of tiny pores that let some compounds pass through, while holding others back. The properties of a membrane can be controlled by depositing various compounds—including catalysts—inside the pores.

In their research, the WPI team is developing a tube-shaped membrane with oxygen-permeable and catalytically active layers lining the interior of the tube. Methane will flow through the center of the tube while oxygen diffuses in from the outside to partially oxidize it.

The team is currently experimenting with ways to control the structure of the membrane to permit only oxygen to pass through. In addition, they plan to deposit electrically conductive materials inside the pores of the membrane to enhance the movement of the electrically charged oxygen molecules.

"We are looking at various oxides that will allow oxygen to permeate through at the high temperatures normally used in the methane dimerization process," Ma says. "By choosing the right material, we hope to be able to control the partial pressure of oxygen and, in turn, control the reaction to produce the best yield possible."

By the end of the three-year contract period, Ma says the team hopes to have developed a mechanism for increasing the yield of the dimerization reaction and to have determined how best to scale the membrane system up to a large enough size to handle the huge volumes of inexpensive methane that are produced by industry.

"For the project to be successful, the process must be economically feasible," Ma says. "We may find that even though the membrane works, it is too expensive to build. Or it may not be easy to use for mass production in an industrial setting. We are hoping we can overcome all these difficulties, but it is a very, very difficult problem. Otherwise, someone would have done it.

"However," he adds, "if the technique works and the conversion rate is high enough, this membrane system could be worth billions of dollars to the chemical, petrochemical and plastics industries."

The Inorganic Membrane Center was established in 1988 to study how the membranes work, how best to make them and how to apply them in a broad range of industries, including the chemical and biotechnology industries. The center includes faculty and graduate students from the Chemical Engineering, Biology and Biotechnology, and Mechanical Engineering departments. Current industrial sponsors include Mobil Oil Corp. and Amoco Oil Co.

—Michael Dorsey

Richard Hansen Is Helping Power Up the Developing World

Felipe Martinez can now regularly keep his country store open past sundown and the local community center can extend its programs well into the evening. Why is that news? Well until a few years ago, there was no reliable source of electricity for lighting in the rural town of Bella Vista in the Puerto Plata region of the Dominican Republic. If the store and community center were occasionally open evenings, shoppers and center visitors were disturbed by the fumes from kerosene lamps.

PHOTOS COURTESY OF ENERSOL ASSOCIATES INC.

Ydalia Alcantara, a Dominican seamstress, works under an electric light powered by one of Enersol's solar electric systems. The systems have replaced dim and smelly kerosene lamps in homes and businesses.

Richard Hansen '76, a professional engineer who received his bachelor's degree in mechanical engineering from WPI and his M.B.A. from Boston University, is the catalyst for these electrifying changes. Nine years ago he founded Enersol Associates Inc., a nonprofit international development organization in Somerville, Mass., that specializes in solar-based rural electrification. He's served since then as Enersol's executive director.

Enersol's goal is to foster rural solar electrification around the globe. Its approach to business, which it calls SO-BASEC, makes use of recent advances in photovoltaic technology and local human and institutional resources to bring power and light to communities beyond the reach of existing distribution networks.

"It's impractical to run traditional electric lines through heavily wooded or remote terrain," says Hansen, a former manager of industrial and manufacturing engineering for Westinghouse. "Besides, it would be bad for the environment."

Hansen went to the Dominican Republic in April 1984 to install one of his first cost-effective, small-scale PV systems at the Martinez home and store in Bella Vista. The system, typical of others installed since then as a result of Enersol's efforts, included a solar photovoltaic module, an automotive battery and a simple control-junction box.

"It provided enough power to run the family's television and radio and to keep lights operating throughout the home and market," Hansen says. "Community members visited, discussed the system, and soon were convinced that the technology suited their needs."

In such a low-income area, paying for systems up front was a problem. So in December 1984, Enersol helped 10 families organize themselves into ADESOL, a solar energy development association. The organization maintains a revolving loan fund that enables people to buy home systems. "It may well be the first solar electric revolving credit fund in the Third World," Hansen says.

The U.S. Agency for International Development mission in the Dominican Republic provided $2,000 in seed money for the fund. By March 1985, five systems had been financed, with users paying about $10 a month for energy services. Buyers pay back the $500 cost for a system over four years. With a community-based credit mechanism in place, Enersol then tackled the problem of system servicing and sales.

"We worked with a local entrepreneur to establish a small hardware and electrical supply store," Hansen says. "The store became the solar service center for the region, a place where customers could order new systems, buy spare parts, request service or arrange short-term financing. Business boomed. Typically, a successfully installed system would result in a number of other sales."

Enersol next trained six local youths to install and service solar home systems. As the young technicians were completing their training, ADESOL received a $3,500 USAID grant to finance systems for eight additional homes and businesses. The work gave the youths immediate practical experience. Peace Corps volunteers attended the second training session, then spread word of the technology to communities where they worked.

With a grant from the U.S. Department of Energy, Enersol and the University of

Massachusetts—Lowell prepared a case study of the organization's activity in the Dominican Republic. The 150-page report described this unique experience of a U.S. company disseminating photovoltaic technology at the grass-roots level in a developing country. It also provided important lessons to others who might choose to follow in Enersol's footsteps.

Between 1984 and 1992, about 4,000 home lighting systems were installed by Dominicans; about half of these can be traced directly to Enersol's training and financing initiatives. Owners say they are pleased with their systems, because they put them in control of their own electrical power. One noted that rural solar system owners are better off than city dwellers who depend entirely on centralized electricity. "While the lights go out daily in Dominican cities," he said, "they stay on in Bella Vista."

Now that solar electric technology has gained a foothold in the Dominican Republic, Hansen is planning similar programs in other countries in Latin America and the Caribbean. He says solar systems can provide these nations with power and light for homes, farms, schools, health clinics and community centers. Unlike other rural energy options, he notes, solar energy systems emit no acid rain or greenhouse gases, use no power lines, and require no dams, mines or refineries.

Enersol has developed a comprehensive program to foster solar-based rural electrification at the community, national and international levels. Its Energy Enterprise Development Activities encourage the creation of local photovoltaic service enterprises that sell, install and maintain systems in remote rural communities. Institutional Support Activities help groups start solar-based rural electrification programs. And Public Outreach and Education Activities provide information about the economic, environmental and technological aspects of photovoltaic systems and their application in the developing world.

Enersol's efforts to aid developing countries have not gone unnoticed. Its Dominican Republic program has received international recognition and support from such institutions as the World Bank, the Central Bank of the Dominican Republic, the USAID Office of Energy, the U.S. Peace Corps, the Electric Power Research Institute, Sandia National Laboratories, Oak Ridge National Laboratory, the United Nations, and the National Rural Electric Cooperative Association.

Technicians Milo Martinez, left, and Cesar Hiraldo carry a solar electric system to a rural home in Bella Vista. Enersol is planning similar programs elsewhere in Latin America and the Caribbean.

Richard Hansen, far right, Enersol's executive director, and Eric Johnson, second from left, the organization's training coordinator, pose with a group of Dominican technicians at a training site in Bella Vista. The technicians install and service Enersol's home solar photovoltaic systems. Since 1984, more than 2,000 systems have been installed in the Dominican Republic as a result of Enersol's efforts.

Early on, Hansen's efforts also caught the interest of WPI Professor Edward N. Clarke, who was then planning WPI's Center for Solar Electrification. The two presented a workshop at WPI on solar electrification in developing countries. One of the first Interactive Qualifying Projects completed through the center, *PV Promotion for Rural Electrification*, was done by Visarut Asvaraksh '88 and Aswin Pinsuvana '89 from Tailand, who benefited from Hansen's early experience in the Dominican Republic.

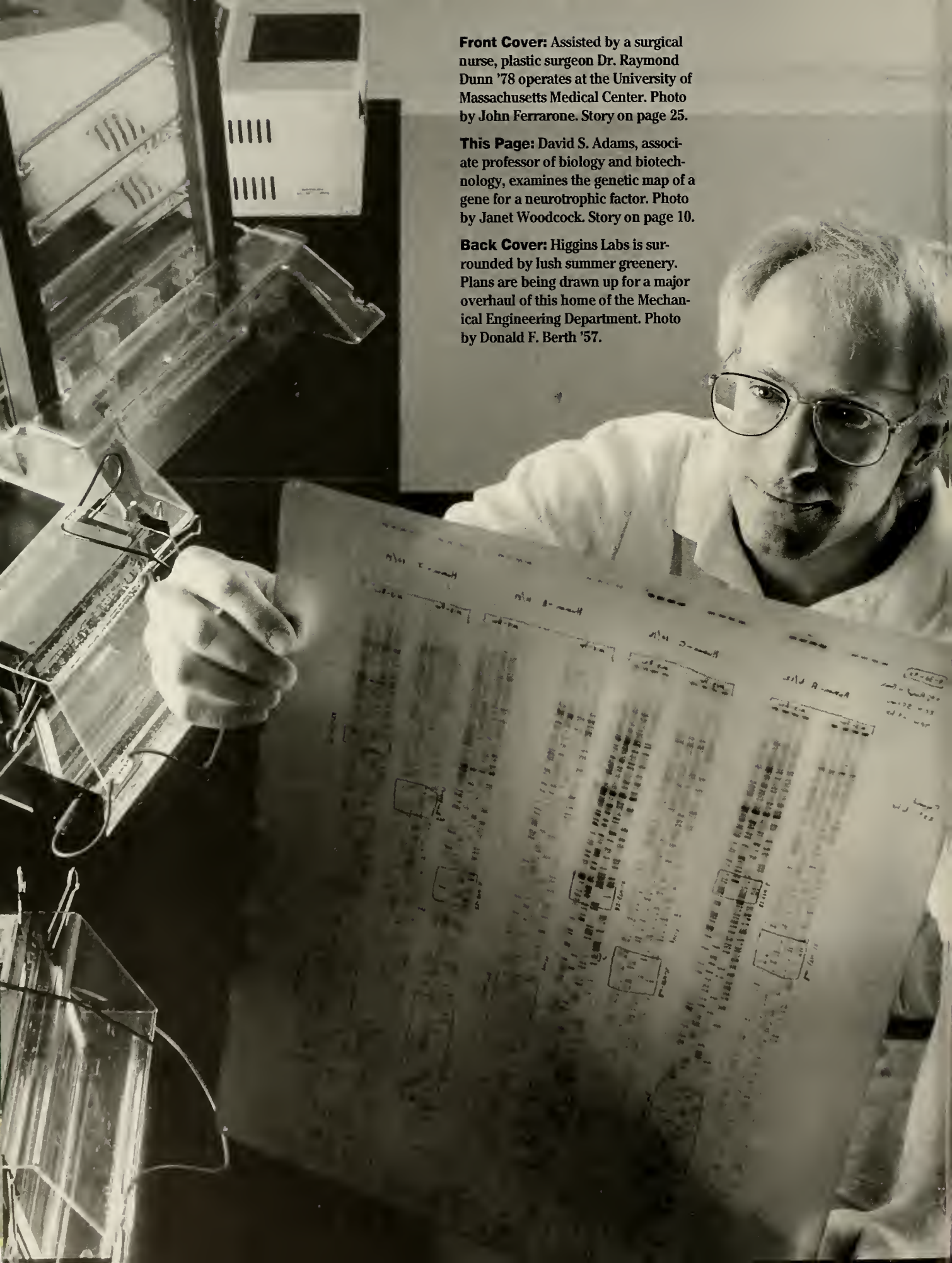
"We've been encouraged by the results of our efforts to date," says Hansen, who has recently been involved in feasibility studies in Belize, Guatemala and Bolivia, and has served as a consultant under contract with the World Bank for the introduction of solar electric technology in Yemen. "But there is still much to be done by everyone. Globally, an estimated two billion people have no electricity."

—Ruth Trask

WPI Journal
WORCESTER POLYTECHNIC INSTITUTE
SUMMER 1993

In Sickness and in Health...

A Special Issue on Medicine



Front Cover: Assisted by a surgical nurse, plastic surgeon Dr. Raymond Dunn '78 operates at the University of Massachusetts Medical Center. Photo by John Ferrarone. Story on page 25.

This Page: David S. Adams, associate professor of biology and biotechnology, examines the genetic map of a gene for a neurotrophic factor. Photo by Janet Woodcock. Story on page 10.

Back Cover: Higgins Labs is surrounded by lush summer greenery. Plans are being drawn up for a major overhaul of this home of the Mechanical Engineering Department. Photo by Donald F. Berth '57.

WPI Journal

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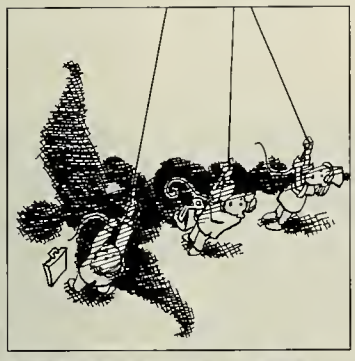

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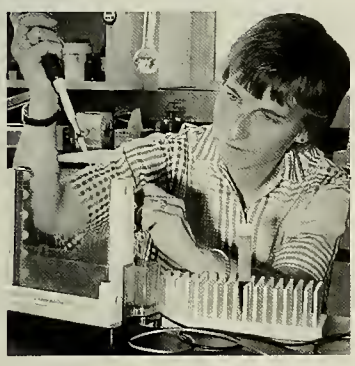

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The Education of a Health Professional

What do WPI graduates do for a living? The answer to that question may surprise you. Many, of course, have adhered to the career paths most often associated with their major fields of study.

But more and more, WPI alumni are using their educations as starting points for lines of work that diverge from these traditional occupations. In the Fall 1991 issue of the *WPI Journal* we focused on alumni who work in the food industry, doing everything from farming to running restaurants. More recently, we profiled engineering and science graduates who've built successful careers as patent attorneys.

"All medical schools look for evidence of independent work or research of the type fostered by the WPI Plan."

Over the past few years, readers of the *Journal* and the *WPI Wire* have met graduates who work as actors, artists, musicians, writers, artists' agents, furniture makers, cartographers, teachers, judges, golf pros, corporate travel managers and pilots. And we are just beginning to scratch the surface.

One field that has traditionally attracted many WPI graduates is medicine. In this special issue of the *Journal* we profile 15 alumni who work as physicians, as well as in a host of other medically related professions. These stories begin on page 25. You will also find—beginning on page 10—a round-up of medically oriented research under way on campus.

For students contemplating careers in medicine, WPI offers the Pre-Health Professions Program, which helps students prepare for careers in medicine, dental medicine and veterinary medicine. Students who want to be veterinarians can also apply to the highly successful B.S./D.V.M. program that WPI offers in conjunction with the Tufts University School of Veterinary Medicine. A select group of high school seniors are admitted each year to both institutions; they will study at WPI and then at Tufts, earning a B.S. in biochemistry, biology/biotechnology or biomechanics from the Institute and a doctorate in veterinary medicine from Tufts.

Through the Pre-Health Professions Program, pre-health professions advisors—Jill Rulfs, assistant professor of biology and biotechnology, and Douglas T. Browne, associate professor of chemistry—provide interested students with advice on the courses they will need to take at WPI to prepare for medical school admission and also help them through the process of taking the Medical College Admission Test (MCAT) and applying to medical schools.

Beginning next year, students will have the opportunity to perform volunteer work at local hospitals, doing such tasks as helping out in medical labs and emergency rooms or serving as patient advocates and translators. According to Rulfs, many students who intend to apply to medical school get additional hospital-based experience through their required WPI projects.

Kim Marquis '88, currently a resident at the University of Washington Medical Center, says WPI's project-oriented education and strong science programs helped prepare her for medical school.

"These projects can give students a real competitive advantage," she says. "They learn a bit more about how the medical system works and make valuable contacts." Last year, about 60 students conducted Interactive Qualifying Projects and Major Qualifying Projects at the University of Massachusetts Medical Center and Saint Vincent Hospital in Worcester, at two hospitals in San Francisco affiliated with WPI's San Francisco Project Center, at the Tufts Veterinary School and at other health-related facilities in the Worcester area. (See "Explorations," page 7, for examples of recent medically related projects.)

The Pre-Health Professions Program is regularly evaluated by the Pre-Health Professions Advisory Committee, which is composed of WPI alumni and other health professionals. On-campus seminars by working medical professionals provide students with insight into current issues in medicine and into the demands and rewards of their prospective professions.

Currently, 87 WPI students participate in the Pre-Health Professions Program. The Class of 1997 includes about 50 members who have already expressed an interest in pursuing a medical career, a

significant jump from recent classes. Each year, between five and 10 students apply to medical schools, a number that is expected to triple within three years due to rising interest among current students.

Rulfs says WPI students consistently perform at or above the national average on the MCAT and are at or above the average in medical school admissions rates. But, she notes, medical school admissions currently "are as competitive as they have ever been." While WPI does not "weed out" any candidate from its pre-health program, as some colleges do, it does advise all students interested in health careers to be prepared to pursue other professions, should they not win admission to medical, dental or veterinary school.

As you will see as you read this issue, alumni who have made the cut and built successful careers as medical professionals consistently look back at their WPI education as a major reason for their success in the field. In particular, the emphasis of the Institute's academic program on self-study and small-group teaching is consistent with the teaching approach of most medical schools, and the experience in problem solving students gain through their projects is excellent preparation for medical diagnosis and research.

Kim Marquis '88 is putting her training to work as a second-year resident in internal medicine at the University of Washington Medical Center in Seattle. She received her M.D. from Duke University School of Medicine. "I felt well prepared for medical school—especially in the area of molecular biology—because of WPI's strong science programs," she says. "I also feel a technical background can be invaluable considering the extensive use of computers and sophisticated equipment in medicine today."

Notes Bruce Minsky '77, who is profiled on page 31, "All medical schools look for evidence of independent work or research of the type fostered by the WPI Plan. There still aren't many undergraduate students who have this kind of experience; it's what distinguishes the WPI applicant from thousands of others applying to medical schools. Being able to independently think a problem through and carry it out from beginning to end is critical, because it's exactly the skill you use when treating patients."

—MICHAEL DORSEY

LETTERS

To the Editor:

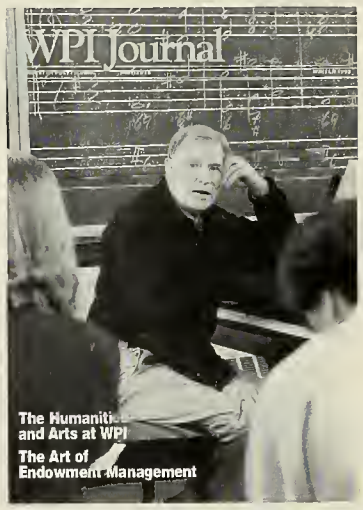
An eager reader of the *WPI Journal,* I found the Winter 1993 issue the most interesting that I have read in 43 years.

From the opening of the first assembly of my freshman class, I recall only one thing. The first speaker was Dean Howe. After approaching the lectern in Alden Memorial, he scanned the assembled class—90 percent World War II veterans–and said, "Gentlemen, look at the man on your left and the man on your right. A year from now, one will not be here and the other will take five years to graduate."

I returned the next year following a successful two semesters of study that I did not find difficult. However, I completed only one more semester, having already decided to transfer to Clark University. That decision was made upon discovering that, while the engineering program was satisfactory, an educational setting wherein most students felt that taking an English course was a waste of time was too stifling an environment for me. I found my satisfaction in degrees from Clark and Harvard.

My associations and friends from WPI have remained strong and I watched with pleasure the introduction of a meaningfully integrated program in the humanities at the Institute. If I had entered WPI at anytime from the 1970s on, I would have been satisfied. I found your latest exposition on the humanities program ("Enriching Life and Making a Living") the most forceful presentation to date.

Carl J. Davis '50, West Burke, Vt.



To the Editor:

I just received my Spring 1993 *WPI Journal* and was most pleasantly surprised to see the Mapparium on the cover. I have been station manager at WCSN, the World Service of the Christian Science Monitor, since 1987. We, along with our other two stations in South Carolina and Saipan, North Mariana Islands, broadcast Monitor Radio worldwide via shortwave.

So with our international involvement, I guess I became involved in the "Global Perspective" before it became "politically correct."

Robert "Stess" Stessel '69, Milford, Maine
(via electronic mail)

To the Editor:

I enjoyed reading "The Whole World in Their Hands" (Spring 1993). It's good to see that WPI is continuing its efforts as a global educator through ongoing expansion of its foreign project centers.

On page 13, it was mentioned that several faculty members are expanding the program beyond the IQP such that students will be able to complete the MQP abroad. I know of one instance where this has already happened. Paul Wojciak '91 and I completed our MQP at the London Project Center during the summer of 1990. Under the direction of Professor Jim Demetry, we evaluated hardware/software/experiments used at several existing controls engineering labs at a number of universities in the London area. The final report made hardware recommendations and outlined a number of controls experiments for use in a much needed (at the time) controls lab at WPI.

Jason Demerski '91, Pittsfield, Mass.
(via electronic mail)

Are We Finally Ready to Rein in the Health Care System?

BY JOHN T. O'CONNOR

By now we're all familiar with the statistics. In the United States we spend more than $800 billion a year on health care—more than $2 billion a day. That's about 14 percent of the total output of the U.S. economy; in other words, we spend about one-seventh of all the income our economy generates on this one service. In comparison, we spent less than 5 percent of a much smaller GDP on medical care in 1950. Even today, England, Canada and most Western nations spend about half as much of their national output on health care as we do.

Though we pay more for it, survey after survey has shown that Americans are less satisfied with their medical care system than residents of other countries. And the U.S. ranks poorly in many of the basic measures of health—including infant mortality—when compared to many other nations.

In the public sector, which pays for about 40 percent of our medical care costs, these higher expenditures—which continue to grow much faster than the rate of inflation—are a cause of great concern. Federal, state and local budgets have taken tremendous hits. As a result, other valuable and necessary items have been crowded out.

In the private sector, it's estimated that 37 million Americans have no medical insurance; another 20 million are thought to be seriously underinsured. This is not just a problem for the unemployed; most of the uninsured have jobs. Rather, it is a direct result of the unaffordably high cost of medical insurance. Ask business owners and they will tell you that they feel that our nation's competitive position in world markets is being drastically undermined by the high premiums they pay each year on employee health insurance policies.

"The postwar expansion of federal funding for medical care was accompanied by massive growth in private sector health insurance."

How did we get into this mess? The current problems in health care in the U.S. began just after World War II, a period that saw the start of a tremendous expansion in the American medical care industry. In other writings I've referred to this time as the "promotive stage" of our health care industry.

Contrary to the predictions of most economists, the U.S. economy did not lapse into recession as the nation demobilized following the war. High levels of postwar liquidity led to enormous levels of pent-up demand (after the Depression of the 1930s and the forced conservation of the defense expansion). Private and public sector revenues expanded significantly, setting the stage for income-elastic industries—like health care—to grow disproportionately.

The federal government responded to this relative affluence by passing legislation that greatly expanded its own role in medical care. The Hill Burton Act of 1946 made billions of dollars available for new and improved hospitals throughout the country. Further billions were provided to finance medical research and to increase the supply of physicians. Perhaps most significant, Congress in 1965 created Medicare and Medicaid to pay for medical care for the elderly and the poor, respectively, adding what currently amounts to hundreds of billions of dollars each year to the cost of medical care delivery.

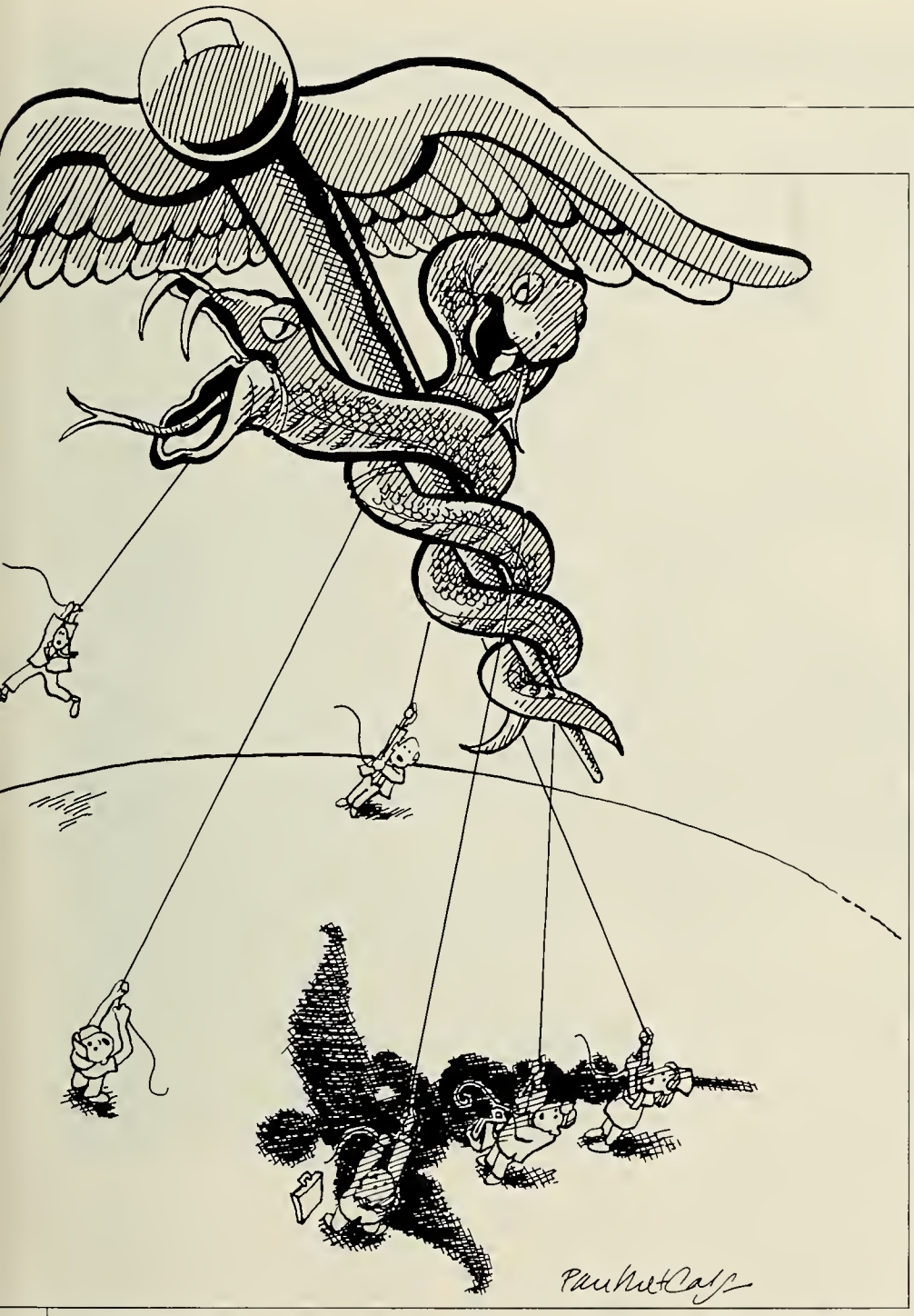
The postwar expansion of federal funding for medical care was accompanied by massive growth in private sector health insurance. In an era of relatively cheap insurance premiums and progressive personal income tax rates, organized labor and management considered it wise to fatten compensation packages with more nontaxable health insurance benefits.

The growth of private and public medical insurance was not only acceptable, but advantageous to organized medicine (particularly to the American Medical Association), for it was based on the prevailing model of solo-practice, fee-for-service, cost-based reimbursement. The insured were allowed freedom of choice in their selection of physicians, hospitals, etc.; controls on the utilization of services were minimal.

By the late 1960s, the consequences of the enormous postwar boost to the medical industry were becoming increasingly apparent. Medical care inflation was out of control, as costs and expenditures skyrocketed. It became clear that a massive redistribution of income and resources had been taking place—away from taxpayers and other private sectors and into the medical care sector.

Washington's first reaction was to attempt to control the problem through regulation. Comprehensive Health Planning legislation, signed by President Johnson, was an ambitious and somewhat naive attempt to rationalize the American medical care delivery system by establishing regional health planning agencies. Although the package funded the education of system planners and created invaluable sets of statistical data, cooperation from health care providers was largely voluntary. In fact, the legislation contained language that required it to be implemented "without interference with existing patterns of private professional practice of medicine...." As a result, the

ILLUSTRATION BY PAUL METCALF



law was a disappointment to many of those interested in reforming the system.

More legislation followed. A 1972 law created Professional Standards Review Organizations to provide peer review of the appropriateness of care and the length of hospital stays for patients covered by Medicare and Medicaid. Many states in the early 1970s adopted "Certificate of Need" laws that required a public body to approve capital expenditures or substantive changes in the services provided by medical providers.

The National Health Planning and Resources Development Act of 1974 consolidated and extended existing legislation, combining elements of regulation, health planning and federal funding for facilities development. It put the federal government in a proactive role in reforming health care in the U.S., its supporters claimed.

Despite of all this legislative activity, medical care expenditures and price levels continued to grow much faster than the GDP. The deregulatory approach of the Reagan and Bush administrations replaced government regulation with attempts to improve market competition. The Republicans wondered why this industry couldn't be made to conform more closely to the economist's model of pure competition.

During this period, funds for health planning, the education of new physicians and the creation of new medical facilities were eliminated or substantially curtailed. Private and public efforts concentrated on making consumers better informed, promoting competitive Health Maintenance Organizations, and reducing the barriers to new suppliers of medical care.

But this strategy has also failed to halt the runaway growth of the medical care industry. What's more, growing numbers of people are either uninsured or paying more out-of-pocket in the form of deductibles and coinsurance. And it's widely believed that the system is still overexpanded—in terms of capital and personnel—and that this excess capacity exacerbates the costliness of the industry.

It's clear that massive changes must be made in the way medical care is financed and delivered in the United States. Regulation and competitive strategies have failed to limit the system's expansion, and an overly expanded system, still financed largely through an expense-promoting, cost-based reimbursement system and fueled by a government- and private-supported network of third-party payers, is capable of consuming virtually unlimited resources.

Medical care is still as much an art as a science; different physicians frequently follow widely varying treatment protocols for the same conditions. Without an incentive system that encourages physicians to make more efficient use of resources and reduces the monopoly power enjoyed by health care providers, there is little hope for beneficial change. On the contrary, with the aging of the population, the AIDs epidemic and the continued expansion of expensive biomedical technology, there is every reason to believe the industry will continue to master an ever-growing share of our economy. It's no wonder that medical care reform was a major issue in the Democratic platform in 1992.

Although the Clinton proposal is long overdue—delayed, in part, by the complexity of the issue and the power of the constituencies involved—its likely components are becoming clear. Managed competition will likely be the delivery system of choice. Under this sys-

tem, provider groups will integrate the financing and delivery of medical care. These "Accountable Health Plans" (e.g., Health Maintenance organizations, Preferred Provider Organizations, etc.) will compete to provide care to the American public.

Patients, or consumers, will be organized into advocacy groups, variously known as "sponsors," "health insurance purchasing cooperatives" and "health alliances." These will establish the standard coverage package, negotiate contracts with provider groups, conduct the annual enrollment/re-enrollment periods, and monitor patient complaints and quality issues throughout the contract period. Large businesses will likely be the sponsor group for their employees. Regional health alliances will serve employees of smaller organizations and the unemployed.

Under the managed care proposal, patients will have primary care physicians who will serve as "gatekeepers," responsible for providing care or directing treatment (access to specialists will require the prior approval of one's primary care physician).

If the administration is to gain approval for its proposal, it must achieve a consensus on the trade-offs of the new system.

Under managed care, the provider group closely monitors the cost and quality of care. Incentives for cost control, absent under the traditional cost-based, fee-for-service delivery system, are inherent in such a system. Without cost control, the provider group cannot establish premiums that will attract patients. Quality considerations are also built in. Excessive complaints will lead consumer alliances to eliminate provider groups from consideration during the next enrollment period.

It's expected that all Americans will be required to participate in this system. Financing is likely to come primarily from employer-paid premiums. Employers above a certain size will be required to participate in the payment of their employees' premiums through a health alliance. The government will share in the cost of providing coverage to the unemployed. It appears that vouchers will be provided to Medicaid participants so they can also be part of the new system; Medicare, however, may remain autonomous.

Although such a system has not been implemented anywhere else in the world, there are good reasons to expect that it will work well in the United States. A medical care system must grow out of—and be consistent with—a country's culture to be successful. Most existing national health insurance programs are single-payer systems in which the government pays for health care through tax receipts. But with our devotion to free enterprise, the U.S. government has traditionally played a less-encompassing role.

The likely features of the administration's proposal conform to our competitive, capitalistic tradition. Financing is primarily through the payment of insurance premiums from the private sector. The delivery system will involve competitive bidding among private entities. The role of the government will be limited. The monopoly power presently in the hands of providers will be limited by the formation of health alliances.

But the government's role will still be substantial. The standard benefit package will have to meet certain requirements. A certain level of employer contribution will be mandatory, as will participation by all Americans. The creation of consumer health alliances will require government involvement. And new governmental financing will be necessary to provide coverage for some of those who are currently uninsured.

But proponents of the plan insist that it is consistent with the "American Way." Its provision of universal coverage will likely appeal to liberals concerned with the access problems inherent in the present systems. There are also plan ingredients that will appeal to conservatives. The role of government will likely be minimal when compared to that in most nations with national health insurance. And decentralized private markets will form the core of the delivery system, permitting consumers to choose from among various provider groups.

Still, passage of any such proposal will not be easy, as consumers and providers will face significant restrictions on their traditional freedoms. HMOs have been around since the 1930s, but while they've seen periods of large enrollment gains in recent decades, they've yet to attract more than a modest share of the U.S. population. The freedom to choose one's provider and see a specialist without prior approval are highly valued (albeit costly) features of traditional indemnity insurance plans; there will be opposition to their elimination.

Many Americans now enjoy employer-financed medical insurance with lavish benefits; they cannot be expected to welcome a more basic insurance package with increased restrictions. And most physicians have traditionally worked with an independence and autonomy that is not characteristic of managed care.

Opposition can also be expected to the increased taxes that will be necessary to finance the system. While increased competition and managed care should ultimately be successful in controlling costs, expanding access to health care and improving coverage for some will cost billions of additional tax dollars. While proposals to increase "sin taxes" on such products as alcohol and cigarettes can be anticipated, additional sources of revenue may be necessary.

Finally, it must be remembered that in the macroeconomy, expenditures equal income. What I pay a physician for a physical examination is an expense to me, but income to him or her. Since the proposed system is designed to control expenditures, it will also control the incomes of providers—institutions and individuals. Not all providers will support the reversal of the redistribution of national income from which they've benefitted for the last half century.

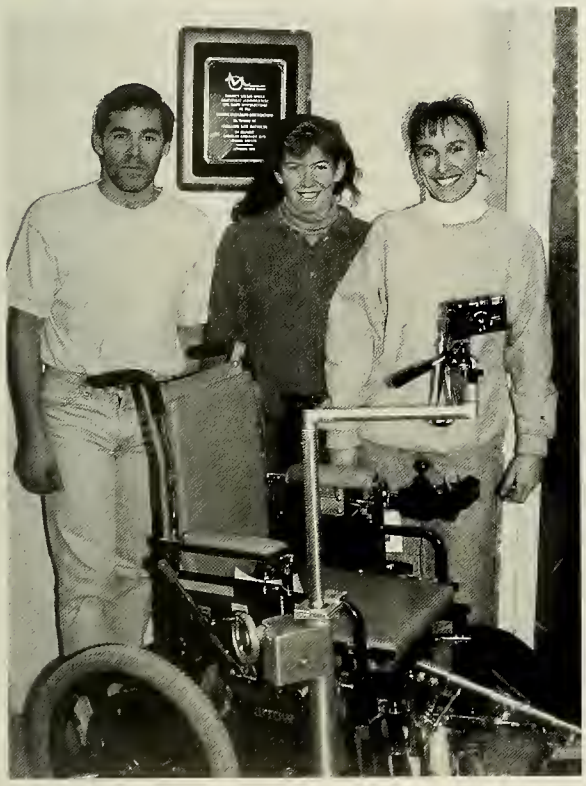
If the administration is to gain approval for its proposal, it must achieve a political consensus on the trade-offs of the new system. While many of the benefits will accrue to low-income groups, those either now uninsured or underinsured, many of the costs will be absorbed by those in the upper income groups. Universal health insurance encompasses many value issues, not only efficiency issues.

While there will be much wrangling over specific details of the proposals, the most important issue may well be the nation's collective reaction to the redistribution of costs and benefits. While we have, as a nation, reached a vague consensus that our medical care system needs reform, we have not fully come to terms with the enormous implications of making such a reform.

O'Connor, a professor in the departments of Social Science and Policy Studies and Management at WPI, has written and lectured extensively about the economics of health care.

Challenging Students and Helping People

For most WPI students, the Major Qualifying Project is an opportunity to solve a realistic design problem in their major field and to learn about how engineering and science are practiced in the real world. But for some 15 to 20 students each year, the MQP means much more—it's a way of helping people gain greater control over their lives and participate more fully in the world around them.



Left, from left, James Woyciesjes, Kathryn Coughlin and Kerry Bagdonovich designed this universal arm for a student interested in photography. Above, this reacher/gripper helps a young student lead a more independent life.

Working with advisors Allen Hoffman, professor of mechanical engineering, and Holly Ault, assistant professor of mechanical engineering, these students complete their projects in rehabilitation engineering, a field that includes the design and development of devices to assist the disabled. Since 1989, projects in this discipline at WPI have been supported by a grant from the National Science Foundation.

Many of the project teams—there are generally between four and six each year, Hoffman says—work with students at the Massachusetts Hospital School in Canton, Mass., a state-supported residential school for students whose disabilities prevent them from attending regular schools. Hoffman says the students work on projects suggested by rehabilitation engineers at the school, developing specialized hardware to meet the needs of individual students. The projects help clients be more independent and participate in a wider range of recreational and vocational activities.

In 1992, for example, in a project that won WPI's Provost's MQP Award and the Edward C. Perry Award for outstanding projects in mechanical design, David Flinton '92 and William Sullivan '92 designed a device to help an 11-year-old with arthrogryposis, a debilitating congenital disorder that greatly reduces the mobility and strength of the joints.

"She has very little grip strength," Hoffman says. "As a result, she drops things—her pencil, her paper, her hairbrush, and so on. Before this project, she had to rely on an attendant to pick them up because she can't reach down from her wheelchair and she can't use commercially available grippers, which require too much strength and coordination."

In a process that is typical of all of the rehabilitation engineering projects, the students first learned as much as they could about the girl's disability. Then, working with engineers and occupational therapists at the school, they observed her physical capabilities. For example, they used a pinch-meter to measure the maximum force she can apply with her fingers, placed objects on the floor around her to gauge her peripheral vision, and attached a wooden dowel to the frame of the wheelchair to see how accurately she can maneuver it.

That last test led to a significant revision to the students' preliminary design. "One of the students placed a quarter on the floor and asked her to see how close she could place the dowel to the center of the coin," Hoffman says. "Her response was to ask if she could keep the quarter if she managed to do it." Needless to say, he adds, she kept the quarter.

Hoffman says her precise targeting ability enabled the students to simplify what had been a complicated reacher/gripper arm. The finished device consists of a motorized aluminum arm that the student lowers over the object after she has wheeled the wheelchair into the proper position. With the flip of a switch, a gripper at the end of the arm closes on the object. The arm is raised once again, bringing the object within her grasp.

"This has really made a difference in her life," Hoffman says. "She can zip about now and do things without having to have someone follow her everywhere she goes. It's really added to her independence."

Here is a sampler of other recent projects in this discipline:

- Kerry Bagdonovich '93, Kathryn Coughlin '93 and James Woyciesjes '93 designed a universal arm and mount for a teenage student with cerebral palsy who wished to take photographs, but was unable to hold or aim a camera. The device also lets her engage in other crafts and use objects like her mirror and hair dryer.
- An "Art Class Assistor," the design of Brendan McLellan '92 and Lap Nguyen '92, makes it easier for students with muscular dystrophy, cerebral palsy and other muscle weakening diseases to draw pictures. It keeps a student's arm off the drawing paper to prevent smearing and enables the student to easily move his or her arm to any spot on the paper.

– John J. Desrosiers '91, Troy Neilsen '91 and James Trapp '91 designed a vehicle powered by two electric motors that provides mobility for children who are too young for wheelchairs.
– A therapeutic tricycle designed by Jennifer Almy '93, Dean Giolas '93, Brian Goetz '93, Eric Graham '93 and Gary Krebs '93 not only lets a youngster with arthrogryposis get around with his friends, but encourages him to use and develop his more seriously affected leg.

Ault says she was particularly impressed with a wheelchair pushcart designed by Donna Underwood '93, Steven Schoeck '93 and Michael Bristol '93 with the help of solid-modeling and finite element analysis software in WPI's CAD Lab. The cart was designed for a student whose job at the school is setting and clearing the tables for meals. The lightweight cart quickly attaches to the front of his wheelchair and has separate molded plastic inserts to hold clean and dirty dishes.

"It really became part of his wheelchair; with practice he was able to wheel it around as easily as the chair alone," she says. "It should have a lot of other applications. For example, it could make shopping much easier for disabled people." She notes that a student project team next year will look at the possibility of gaining wider distribution for this and other student projects.

Ault says rehabilitation engineering projects have proven especially popular at WPI because they let students solve real problems for real people. But she notes that they also provide outstanding training in design, as they require students to go through the entire design process—from identifying a problem, to conducting a detailed design and engineering analysis, to making and testing a prototype, to producing a usable device.

"The requirement we place on students is that they deliver a working device," Hoffman adds. "We won't settle for anything less. But we find that the fact that these devices will actually be used by disabled individuals provides a strong motivation for students to follow through. And the students get a great deal of satisfaction from helping these people out."

—MICHAEL DORSEY

NEIL NORUM

From left, Jesse Spencer, Jonne Helenius, Sean Kavanaugh and Professor Douglas Walcerz with the cardiac massage simulator the students designed.

Shape Memory Study is a Winner

For their Major Qualifying Project, Nancy Lynn Koczera '93 and Walter C. Kretzer Jr. '92 investigated surgical staples fabricated from shape memory thermoplastics. In April, a paper about this MQP earned first place (out of 40 papers) in the Undergraduate Student Paper Competition at the 12th Southern Biomedical Engineering Conference in New Orleans.

Koczera and Kretzer studied thermoplastics, which can be shaped at high threshold, cooled, then reformed. If the temperature is raised above a certain temperature, the polymer will return to its original shape. These materials have applications to a wide range of products and industries, from toys to medicine.

For their research and report, Koczera and Kretzer tested polymer compositions to determine which combination would be the best replacement for the stainless steel fracture-fixation devices currently used to hold healing bones in place. Physicians have come to recognize that polymers, which are similar in density to bone, allow broken bones to heal without the slight osteoporosis that can occur when steel devices are used. In addition, these polymers are gradually resorbed into the body, eliminating the need for surgical removal of the device. Satya Shivkumar, assistant professor of mechanical engineering, and David DiBiasio, associate professor of chemical engineering, were the project advisors.

—BONNIE GELBWASSER

Building A Cardiac Massage Simulator

The operation is progressing normally, when, without warning, the patient goes into shock. His heart beats rapidly, then stops. Faced with this life-or-death situation, a surgeon has several choices. If other life-saving measures fail to get the heart going again, he can open the chest and massage the heart.

Surgeons routinely use open-chest cardiac massage (OCCM) to resuscitate patients during open-heart surgery and in a number of other situations; veterinarians use it even more frequently because the rib cage of many animal species makes external heart massage relatively ineffective. Until now, most medical and veterinary students received limited hands-on training in open-chest cardiac massage because of the cost of laboratory exercises and the ethical necessity of minimizing the use of laboratory animals.

WPI students Michael T. Clohecy '93, Jonne Henrik Helenius '93, Sean M.

Kavanaugh '93, Kevin M. Lord '93, Jesse W. Spencer '93 and Jessica M. Young '92 have applied for a patent for their Open-Chest Cardiac Massage Simulator, a working prototype of the heart that can be used to demonstrate and practice the proper ways to administer the procedure. It is expected to be an important teaching tool for medical and veterinary students and for other health care professionals. It could also be used by these individuals to review and practice their technique during their careers.

Five of the students worked with Douglas B. Walcerz, assistant professor of mechanical engineering, and Dr. James Ross, professor and chairman of medicine at Tufts University School of Veterinary Medicine in North Grafton, Mass., to design a device for simulating OCCM. The project was initiated in 1992 by Jessica Young.

The simulator consists of a hollow silicone heart attached to a system of tubes, valves and reservoirs that model venous and arterial input and output to provide tactile feedback to the practitioner through variable flow rates and pressures. The team studied a sheep's heart they obtained from a slaughterhouse before creating an aluminum and later a silicone model.

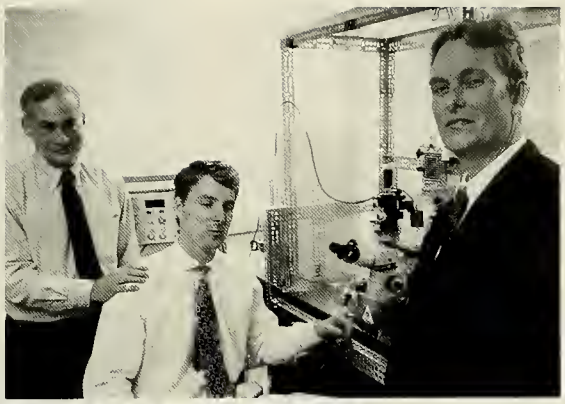
"The model has the look and feel of a real heart and is designed to be filled with liquid —probably a water/glycerol mix," says Walcerz. "It is fitted with tubes with valves on them to enable the instructor to simulate actual conditions like shock and vasoconstriction, so the student can actually feel what is happening."

—BONNIE GELBWASSER

Helping Physicians See More Clearly

For their Major Qualifying Project, Richard J. Bombard '93, Douglas F. Finkle '93 and Mark Turbitt '93 completed a study that will help physicians and scientists more accurately see why and how cells act the way they do.

Using digital technology and light microscopy, biologists and clinicians have been able to observe fluorescent dye-stained cells under powerful microscopes to see and better understand the complex changes that can take place in the molecules and ions in living cells. This knowledge can play an important role in diagnosis, and ultimately treatment, of illnesses and diseases.



NEIL NORUM

From left, Dr. Fredric Fay of the UMass Medical Center with Douglas Finkle and Mark Turbitt, who studied several algorithms used in digital image restoration.

For example, within the last few years a protein defect has been identified within the genes of cystic fibrosis patients and the concentration of calcium ions in smooth muscle cells has been shown to have a significant role in hypertension, asthma, bladder disfunctions, kidney disease and gastrointestinal disturbances.

Before the development of this new microscope technology, it was not possible to observe complex intercellular processes. Normal light microscopes are plagued with optical distortions, known as aberrations. But optical aberrations can be reversed if they can first be accurately measured and mathematically described. This process is known as image restoration. Using powerful computers, image restoration and feature-enhancement techniques are being used to produce three-dimensional images of cells. But, because the science is so new, some restoration techniques produce visually and numerically inaccurate images.

Bombard, Finkle and Turbitt, who received bachelor's degrees in electrical and computer engineering in May, worked with a team of scientists from the Biomedical Imaging Group, part of the Physiology Department of the University of Massachusetts Medical School in Worcester, to test and compare the performances of several restoration algorithms currently in use. Algorithms are roadmaps or blueprints that tell scientists which steps to follow to make best use of their experimental information.

The students' goal was to ascertain which of several restoration algorithms produce the most accurate images under a variety of test conditions. The test results will help biologists and clinicians increase their understanding of complex cell structures and processes. The WPI faculty advisors were Denise W. Nicoletti, assistant professor of electrical and computer engineering, and Michael A. Gennert, assistant professor of computer science.

"The students acted effectively to test a number of algorithms that have been proposed to enhance resolution," says Dr. Fredric S. Fay, director of the Biomedical Imaging Group. "Their results have long been awaited by the field and represent much needed, careful and unbiased analysis. Their work will provide useful guidance for biomedical researchers interested in using digital imaging microscopy throughout the world." Fay's laboratory is world renowned for pioneering a novel approach to digital imaging microscopy.

The students developed a number of computer models as test images, established testing criteria that can be used for future tests, and wrote process-control software to automate the testing procedures. They determined that the most accurate algorithm of those presented for study was the least squares regularization with non-negativity, which was developed by Walter Carrington, a mathematician from the Biomedical Imaging Group who was an assistant professor of mathematical sciences at WPI in 1984-85. They presented a summary of their project at the December meeting of the WPI Board of Trustees.

"This project fulfilled the technical requirements of an MQP because the students learned techniques of software engineering, microscopy, simulation and restoration algorithms, and model testing," says Nicoletti. "Engineering design must be included in any MQP; the design components of this project were the selection of algorithms, efficient coding of the algorithms, creation of automatic and user-friendly interfaces for model testing, and appropriate statistical measurements of the model performance. This project was particularly rewarding because it combined advanced, theoretical topics from electrical engineering with the solution of an important scientific problem."

—BONNIE GELBWASSER

A roundup of explorations under way in WPI's research laboratories aimed at advancing the leading edge of medicine

Fantastic

By Michael Dorsey

All over the WPI campus, faculty members and students—from undergraduates on up to postdocs—are conducting research that is opening new frontiers in medicine. In this one article, we can highlight only a small sample of this exciting work. Watch future issues of the WPI Journal *and* WPI Wire *for more stories about ongoing research in medicine and many other disciplines.*

Pioneering New Ways to Detect and Treat Stroke

Since it was first developed in the late 1970s, magnetic resonance imaging, or MRI, has become a powerful tool for probing the body for signs of cancer and other diseases. This technique employs a combination of a strong magnet and radio signals to produce detailed images of the body's internal structure.

In recent years, new techniques have been developed that have greatly expanded the capabilities of MRI. In pioneering research undertaken over the past few years by a consortium of medical research groups at WPI and six New England hospitals, a combination of novel MRI techniques and new drugs is providing, for the first time, a method for detecting the onset of stroke and treating it before devastating brain damage occurs.

Stroke is the third leading cause of death in the U.S. The condition occurs when an artery feeding blood into the brain becomes blocked, often by a blood clot, depriving nerve tissue of oxygen and energy—a condition called ischemia. Almost immediately, a small region of brain cells dies, but cells surrounding this core, although compromised, can recover if treatment begins soon enough.

Unfortunately, standard methods of diagnosing stroke—including conventional MRI—cannot detect the signs of ischemia until several hours after the flow of blood ceases. By that time, the damage is generally irreversible. In fact, many neurologists believe treatment must start within the first hour of a stroke to have any chance of success.

As part of a consortium that includes the University of Massachusetts Medical Center and the Medical Center of Central Massachusetts, WPI's Magnetic Resonance Research Center has been evaluating the ability of several new MRI techniques to detect the early effects of stroke. One of the most promising of these new techniques is called diffusion-weighted (DW) MRI. In this method, signal intensity in the image is proportional to the diffusion coefficient of water, a measure of how readily water molecules move through a medium.

Christopher H. Sotak, associate professor of biomedical engineering and director of the Magnetic Resonance Research Center, and his research collaborators have been exploiting the fact that DW MRI can detect an ischemic region of the brain far more quickly after the onset of stroke than other diagnostic techniques. While four to six hours can pass before the effects of stroke become apparent in conventional MRI images, DW MRI can spot an ischemic region in as little as 15 minutes after the cessation of blood flow, Sotak says.

The increased signal intensity observed in a DW MRI image is a reflection of a decrease in the apparent diffusion coefficient, or ADC, of water in the ischemic region. The change in ADC is most likely related to the disruption of high-energy metabolism.

High-energy metabolism drives the so-called "sodium pump" in the membranes of cells. This pump maintains the proper balance between the concentration of sodium inside the cell and in the extracellular spaces. As the pump fails during ischemia, extracellular sodium rushes into the cell, initiating a cascade of biochemical events that includes the accumulation of water and calcium in the cell, cell swelling and, ultimately, cell death.

Many therapeutic strategies for stroke involve the design of drugs that attempt to retard the biochemical mechanisms that lead to cell death. These include the release of toxins, like glutamate, from damaged cells. Glutamate latches on to nerve cell membranes and lets calcium flood in, killing the cells. The New England consortium of which Sotak and his team are members is studying the effectiveness of a drug developed by Cambridge Neuroscience Inc. Known as Cerestat, the compound blocks channels in the cell membrane that allow calcium to flow in unchecked.

"In our MRI studies, we've seen a 50 percent reduction in the size of the ischemic region as a result of this treatment," Sotak says. "Based on these studies, the FDA has approved the drug for human clinical trials." The trials, which began in the spring, will study the effectiveness of the combination of diffusion-weighted MRI and Cerestat in diagnosing and treating patients who show symptoms of stroke.

In related work, Sotak has been working with graduate student Lawrence L. Latour to better understand the mechanism responsible for the decrease in the apparent diffusion coefficient during ischemia. They are using a simple model system that consists of closely packed red blood cells.

To simulate the biochemical processes that occur in stroke-damaged cells, Latour and Sotak reduced the salt concentration in the extracellular spaces, causing water to rush into and swell the cells. As water flowed in, the volume of water in the extracellular spaces shrank. This caused a characteristic change in the diffusion coefficient in these spaces, a change that was readily measurable with the laboratory's magnetic resonance instrument.

What was particularly striking, Sotak notes, is that the diffusion coefficient decreased by 40 percent, a value quite similar to the magnitude of the reduction that has been measured in brain tissue damaged by stroke. In normal brain tissue, water is displaced an average of seven to eight microns every 40 milliseconds (the measurement time in the MRI experiment). In stroke-damaged brain tissue, the average displacement is reduced to about five microns in 40 milliseconds. "This decrease has been observed for about five or six years," Sotak says, "but there hasn't been a good explanation for why it happens."

Some theories have suggested that, when deprived of energy, the active transport mechanism inside brain cells shuts down, reducing the movement of fluids in the cell and lowering the diffusion coefficient. Others focus on the failure of the sodium pump during ischemia, which lets water rush into and swell the cells. "Our work indicates that it is really the shrinking extracellular volume that is behind the characteristic reduction in this parameter," Sotak says.

Voyages!

JANET WOODCOCK

Graduate students Bernard J. Dardzinski and Mary Ferrera work in WPI's Magnetic Resonance Research Center. The insert shows what happens to brain cells during a stroke. As energy is cut off to a cell, the sodium pump in its membrane fails. Sodium rushes in, causing the cell to swell with water. The damaged cell releases toxins, which let calcium flood through the membrane, killing the cell.

Shedding New Light on Diabetes

As the 1.4 million Americans who suffer from the Type I form of the disease well know, diabetes remains a disease without a cure. The insulin injections diabetics take several times a day to regulate their blood sugar greatly curtail the damage the illness can do to the heart, blood vessels, eyes, nerves and kidneys. They can be reduced still further with more aggressive monitoring of blood sugar, a recently concluded study by the National Institutes of Health noted. But no matter how carefully administered, insulin can't eliminate the progressive deterioration of the body that diabetes causes.

In fact, the disease remains the leading cause of kidney failure and new cases of blindness in those over 65 and is the nation's fourth leading cause of death. Before diabetes can be cured, scientists will have to get a better handle on its root causes.

The most overt symptom of diabetes is the inability of the body to produce insulin. Manufactured in the pancreas, insulin helps the body regulate the amount of glucose circulating through the bloodstream. When there is too much glucose, the body removes the

sugar from the blood and stores it as glycogen in the liver and muscles.

A great deal of research on diabetes has focused on the biochemical pathways involved in the storage of glucose. Insulin's role in this process is to activate an enzyme known as glycogen synthase, which, in turn, helps link individual molecules of glucose into glycogen, notes Jill Rulfs, assistant professor of biology and biotechnology, who became interested in this process as an instructor in the Biochemistry Department at the University of Massachusetts Medical Center.

JANET WOODCOCK

Jill Rulfs at work in the new Fairlawn Foundation Laboratory at WPI. Rulfs is working to understand the biochemistry underlying diabetes.

At UMass, where Rulfs serves today as an adjunct assistant professor of biochemistry and molecular biology, she was part of a team studying glycogen synthase and attempting to clone the gene for this protein. In the process, the team became interested in another protein that plays an even more fundamental role in glycogen formation.

"Glycogen synthase cannot start with one glucose molecule and build from there," she says. "It needs a primer of six or seven glucose molecules already strung together. Back in the 1970s, people realized that there had to be another protein that could make this primer. That protein is now known as glycogenin."

While the effect of diabetes on the quantity and activity of glycogen synthase has been extensively studied, she says, to date no one has looked at how the disease affects glycogenin. With a three-year, $104,000 grant from the National Institutes of Health, Rulfs is taking on that challenge. Working at UMass and in a new laboratory at WPI funded by the Fairlawn Foundation in Worcester, she is studying glycogenin in the liver and muscle.

In work completed so far, undergraduate Nestor Deocampo '93, as part of his Major Qualifying Project, found the protein in samples of normal liver and muscle tissue using an antibody probe developed in Rulfs' lab. "It appears that there is more of the protein in the liver, although the forms present in the two types of tissue may be significantly different," Rulfs says.

The next step will be to determine the amino acid sequence for each type of protein to see where the differences lie. This may provide clues as to whether glycogen synthesis works differently in the liver and muscle and whether diabetes has different effects on glycogen storage in these organs.

Then, using a special strain of rat that spontaneously develops diabetes, Rulfs and a new team of undergraduates will see whether the disease alters the amount of glycogenin produced by the body and whether the structure of the protein is different in any way in the diabetic rats.

"If the diabetic rats have the protein," she says, "we want to see if there is a change in its ability to attach to glucose and build the primer for glycogen synthase." It may turn out, she notes, that the real problem in diabetes and other glycogen-storage diseases lies in the creation of this primer. Or, it may be that the same mechanisms that affect the activity of glycogen synthase also affect glycogenin.

In other research, Rulfs has been looking at the molecular changes that underlie the damage diabetes can do to the heart. "Diabetic hearts are hypersensitive to adrenaline," she says. "For example, very low levels of adrenaline will cause heart cells to beat faster. We want to understand the molecular basis of this hypersensitivity.

"Clearly, there is some information that is being translated from the cell membrane into the cell that causes this reaction. We want to elaborate the mechanism by which this happens. What is the signal from outside the cell? Is it insulin, some other growth factor, or another compound? How does it get into the cell, and once there, how is its message transmitted."

To do this work, Rulfs uses rat heart cells that are cultured in the lab. While a single heart can be used to create multiple cultures that can be exposed to multiple experimental conditions, each new experiment requires the sacrifice of a new animal, Rulfs says. To avoid this requirement, Rulfs is working with doctoral candidate Caroline E. Miller to develop an immortal adult cardiac cell line.

An immortal cell line is made up of cells of a certain tissue that will continue to grow and divide indefinitely in culture and still maintain all the original characteristics of the tissue. It provides researchers with a virtually unlimited source of tissue for experimentation without the continual need for sacrificing animals, Rulfs says.

Normally, many mammalian cells, like heart cells, do not grow or divide once they are removed from the body. To jump-start them, scientists transform the cells with a virus that inserts a gene into the cell's chromosomes that overrides built-in checks on cell growth; the transformation is similar to the genetic changes that cause cancer cells to grow and divide uncontrollably.

To date, the cell line established by Rulfs and Miller, with support from the American Health Assistance Foundation, has

undergone 20 passages. Passaging is the process of subdividing a growing cell population by transfering cells from one culture vessel to several others. The process gives the cells room to keep growing.

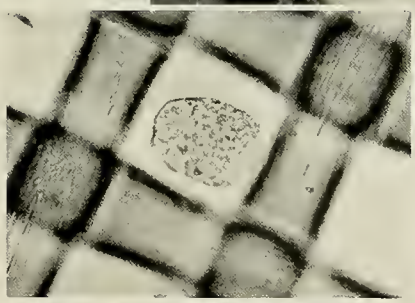
Miller has analyzed the first 12 of these "passages" and confirmed that the cells continue to show all the characteristics of adult heart cells and still seem to have the gene for unlimited growth in their genome. In addition to its value in her own research, Rulfs says the cell line should prove useful to researchers doing many other types of studies on the physiology and pathology of the heart.

Putting Living Tissue in the Deep Freeze

During the 20th century, medical researchers have developed techniques that use tissue from human donors to treat illnesses, to restore normal bodily functions and—in many cases—to save lives. While procedures like heart and liver transplants have grabbed the headlines, millions of patients have regained their sight after cornea transplants, burn victims have been saved with skin grafts, infertile couples have had children thanks to donated sperm and eggs, and countless accident victims, surgery patients and hemophiliacs owe their lives to donated blood.

Living cells undergo steady deterioration after removal from the life-giving systems of the body. This can be slowed by refrigeration at 4°C coupled with nourishment with specially designed solutions. But even in the best of circumstances, tissue remains viable for only a few weeks. The goal of unlimited storage with no loss of function has been achieved in a few tissues by freezing them at -196°C. The potential exists for many more tissue types to be preserved in this way.

JANET WOODCOCK



Douglas Walcerz and graduate student Alison Berube prepare to freeze cells in a cryogenic microscope stage Walcerz designed and built. He and Berube are using the stage to learn how best to freeze pancreas islets (insert), the source of the hormone insulin.

Cryopreservation, as the freezing of living tissue is known, has proven to be as much an art as a science, notes Douglas B. Walcerz, assistant professor of mechanical engineering. "Most of the tissue we currently preserve—blood, skin, embryos, and so on—can be frozen and thawed pretty reliably," he says. "But each time we begin looking at a new tissue we run into new problems. Tissues are so diverse and cell types so different from one another, that there is no one freezing and thawing method that will work for everything."

In his cryobiology laboratory at WPI, Walcerz is bringing an engineering perspective to what has largely been the domain of medical researchers. "In the past, most cryopreservation methods have been developed with a purely experimental approach," he says. "Tissue is frozen and studied, and then the freezing rate or conditions are varied and the process repeated until the best method is discovered."

Over the last seven years, Walcerz has been developing a thermodynamic model of the cryopreservation process that can be used to predict how fluids and chemicals will flow across the cell membranes in the target tissues and how various factors—such as excessive dehydration and ice formation—may injure or destroy the cells. "Ice formation is almost always fatal," he says, "because the rigid crystalline structure of ice will grow right through the cell membrane."

To make sure the model accurately reflects what happens in actual tissue, Walcerz spends about half of his time freezing and thawing tissue in the laboratory and studying how its properties change. For these studies, he uses a special computer-controlled microscope stage he developed while completing his Ph.D. at the University of Texas at Austin.

The patented stage enables a scientist to continuously view cells as they are prepared for freezing and ultimately frozen and thawed. The cells are placed in a sealed chamber into which various solutions and refrigerants—such as nitrogen vapor—can be introduced and removed. A video camera records the whole process for later study. Walcerz says the stage is a major improvement over previously available technology.

"This is a much more versatile stage," he says. "With previous stages, you could adjust the freezing conditions or the chemical environment, but not both simultaneously. The other stages also had no means for nucleating ice—in other words, for starting ice formation in a controlled manner. If you don't do that and let the ice form spontaneously, it usually appears with a sudden burst, which is quite destructive."

Walcerz has been using the stage to study the freezing and thawing of pancreas islets. "The islets are the only insulin-producing tissue in the body," he says. "The goal of a number of research teams is to be able to transplant islets into diabetic patients—or to place them in artificial pancreases—to give these people the ability to produce insulin.

"There are about one million islets distributed in clusters throughout the human pancreas. Each one is slightly smaller than a grain of salt, and they have proven quite difficult to separate from the rest of the tissue. Because the separation yields are so poor, it takes four or five donors to get enough islets to do one transplant. Since all of the islets have to come from donors whose tissue is com-

patible with the recipient, it can take some time to acquire them all. That's why there is a great need to be able to freeze islets."

The freezing process for any tissue is a delicate chemical ballet, Walcerz says. It involves cooling the cells, adding chemicals that act as antifreezes and then quickly lowering the temperature of the cells with refrigerants. Because most antifreezes are toxic, they must be added in just the right quantities and when the cells are already cool, since their toxicity is directly related to temperature, though not too cool, since the permeability of the cell membranes also decreases as the temperature drops.

Because of the complexity of this process and the time-consuming nature of lab work, Walcerz says his computer model can help him arrive at acceptable solutions far faster than experimentation alone. The model will also ultimately reveal far more about the changes that take place in the islets as they are frozen and thawed and how to avoid the damage freezing can cause.

"The theoretical basis for this model has been in place for three decades," he says. "The actual writing of the computer code has not been as straightforward as one might imagine. There are a lot of parts that surprise you and explode when you try to run them on the computer."

Walcerz says the model is essentially complete. He is now developing a more user-friendly interface that will enable scientists not steeped in thermodynamic modeling to use it to predict the outcome of freezing processes. He is also beginning to apply the model to other tissues.

He is currently working with corneas, trying to discover why corneal cells survive freezing even as the corneal tissue falls apart. "This is proving to be a very difficult tissue to preserve," he says. "It's another twist in an ever-surprising field."

In the sequence above, a blood clot in a coronary artery is eliminated with a clot-dissolving drug. David Adams has developed a longer-lasting form of the clot dissolver urokinase. Normally, urokinase (uPA in the diagram at right) binds to an inhibitor (PAI) and then to a receptor, which quickly clears it from the blood. The new form of urokinase (Mut-uPA) does not bind to the inhibitor.

Engineering a Longer-Lasting Clot Dissolver

On a hot summer evening, the doors to a hospital emergency room swing open as EMTs wheel in a middle-aged man complaining of severe chest pains. In short order, the patient is hooked up to an intravenous line as urokinase is fed into his bloodstream to dissolve a clot blocking the flow of oxygen-rich arterial blood to his heart.

Urokinase is one of a class of drugs called clot dissolvers. Like TPA (tissue plasminogen activator), another widely used clot buster, it is a protein that is produced naturally by the body to break up clots that form constantly as a result of normal activities like sitting or walking.

The clot dissolvers in use today are genetically engineered versions manufactured in mammalian cell cultures. While they have proven to be lifesavers, they all suffer from an important drawback: because the body quickly inactivates these compounds and clears them from the bloodstream, they must be administered in rather large quantities.

"Urokinase has a half-life of about two minutes," notes David S. Adams, associate professor of biology and biotechnology. "The body gets rid of these proteins quickly so it can maintain the vital ability to form clots. But that means that when you're using them clinically, you have to keep adding more and more to make sure you dissolve the clot you're after."

With support from the National Institutes of Health and Transgenic Sciences Inc. in Worcester, Adams and a team of students that included Loree Griffin '91, set out several years ago to develop a second-generation urokinase that would be equally effective in busting clots, but more resistant to breakdown by the body.

The first step in the process was to determine the exact sequence of the amino acids that make up urokinase. Having accomplished that, Adams began studying the sequence to see if he could identify the specific amino acids that form the active sites that create the chemical bonds that link urokinase to another protein called an inhibitor. The inhibitor not only deactivates the clot dissolver, but makes it possible for white blood cells to absorb and destroy it.

"I reasoned that if I could determine how urokinase binds the inhibitor," Adams says, "I could make a change in the gene that codes for this protein that would not only prevent the inactivation of urokinase, but slow its clearance from the bloodstream."

Adams used a computer to compare urokinase's amino acid sequence to those of similar proteins, only one of which—TPA—also binds the inhibitor. Adams found a segment that is present in urokinase and TPA, but which does not occur in the other proteins. He decided that this might well be the binding site.

To test his hypothesis, Adams first cloned the gene for urokinase and then excised that part of the genetic sequence that codes for this site. The altered gene was then introduced into a cell culture, which manufactured the new version of the protein. The final stage was isolating and testing the compound, Adams says.

First, the new urokinase was applied to blood clots to confirm that it had not lost its ability to dissolve them. It was then added to test tubes containing the inhibitor protein to confirm that it does not bind to it. Other tests demonstrated that the new urokinase remains active in blood far longer than the natural or wild form.

"The next step will be to conduct animal tests to measure the half-life of the protein in the bloodstream," he says. "We're predicting that the half-life will be around 45 minutes. This means that it should be possible to get the same clot dissolving effect using 10 times less drug." Adams says there are other potential modifications to the urokinase molecule that might increase its activity or longevity. These may become future projects for WPI students.

Currently, Adams is applying the techniques he used in the study of urokinase to compounds known as neurotrophic agents. "We all have neurotrophic agents in our brains," he says. "They're capable of causing neurons to grow toward them and can alter the firing capability of neurons. Their ability to stimulate brain cell growth is something that was once thought impossible."

Adams says the first neurotrophic factor, ependymin, was discovered in goldfish more than two decades ago by Victor Sashoua, a researcher at Harvard. Adams is currently conducting research on neurotrophic agents with funding from Neuromedica Inc., a company founded by Sashoua.

Ependymin appears to consolidate memories by depositing itself around new neural connections that form as memories are created in the brain, making those connections—and the memories—permanent. Ependymin formed to consolidate a particular memory seems to be able to transfer that memory to another brain by forming and hard-wiring similar neural connections there.

Sashoua discovered this property by first training goldfish to swim upside down. He then recovered ependymin from the brains of those fish and injected it into untrained goldfish, which learned the task much faster than the original group of fish.

In his lab, Adams has cloned the gene for goldfish ependymin. Using a portion of the gene as a probe, he and a team of students are employing a technique called the polymerase chain reaction (PCR) to scan the genomes of other species for similar genes. So far, they have found such genes in species ranging from horseshoe crabs to monkeys.

In related work, undergraduates Amy D. Brideau '92 and Christina G. Corria '92 cloned the gene for amyloid, the predominant protein in a substance called plaque that forms in the brains of Alzheimer's disease sufferers. They then created mutations in the gene that mimic those seen in people who develop a form of Alzheimer's that appears relatively early in life.

The gene the students developed has been used by TSI Corp. to create a strain of transgenic mice that will, Adams hopes, develop the symptoms of early-onset Alzheimer's. "TSI wants to see how these mice react to drugs that may prevent Alzheimer's," he says. "There is currently no reliable animal model to use in such tests. In addition, if the animals get Alzheimer's, it will add weight to the theory that the plaque causes the symptoms of the disease, which is by no means clear now."

Expanding the Boundaries of Medical Ultrasound

Since it first appeared in hospitals in the 1970s, medical ultrasound has become an essential diagnostic tool that enables doctors to noninvasively probe the body, capturing images of everything from an unborn fetus to a developing tumor to a malfunctioning heart valve.

But while ultrasound technology has advanced significantly over the past two decades, a considerable amount of work remains to be done to expand its capabilities. Some of that work is under way in the laboratory of Peder C. Pedersen, professor of electrical and computer engineering at WPI.

Much like sonar devices, ultrasound scanners work by using a transducer to direct high-frequency sound waves into the body and then analyzing the sound energy as it is reflected back to the transducer. The amount of energy returned and the arrival time of the echo provide information about the nature of the reflecting tissue and its distance from the transducer.

JANET WOODCOCK

From left, graduate students Brita Sorli and Javier Berrios and Professor Peder Pedersen work in Pedersen's laboratory, where the three are developing ways to expand the capabilities of medical ultrasound.

Some scanners process the received echoes to extract slight frequency changes—called Doppler shifts—that enable the scanner to image the movement of blood through heart valves and blood vessels. Because moving blood cells reflect only a minute amount of sound, Doppler ultrasound devices send out short but fairly intense sound pulses.

With funding from the National Science Foundation, Pedersen has been working to develop a new type of Doppler ultrasound technique that avoids exposing the body to powerful sound pulses. (While no deleterious effects of such powerful ultrasound pulses

have been documented, that possibility is nonetheless a concern to researchers, Pedersen says.)

Pedersen's system sends out sound energy in the form of a long, gliding tone, rather than a brief pulse. "While the total amount of energy delivered may be equal to or higher than that emitted by pulse Doppler systems, it is sent out over a much longer time interval," he notes. As a result, the ultrasound signal impinging on tissue is of a much lower intensity than that of a conventional pulse Doppler system, even though the new Doppler system has the same capabilities for imaging blood flow.

Much work is still needed to assess the clinical usefulness of the new system, Pedersen says. Toward that end, graduate student Brita J. Sorli, in work that culminated in her master's thesis this past spring, developed and tested new signal processing methods that promise to make the new Doppler system faster and more accurate.

In other research, Pedersen and postdoctoral student Javier C. Berrios are developing a new method for using ultrasound to detect blood vessel pathologies, such as blood clots in veins. Currently, to locate clots doctors commonly use such invasive methods as venography, in which a contrast agent is injected into the vein and blood flow is monitored with X-rays. While Doppler ultrasound can be used to search for clots, it is limited because of the difficulty in distinguishing between the slowly moving blood in open veins and the stationary blood in blocked veins.

The technique Pedersen and Berrios are exploring is a refinement of a trick ultrasound sonographers sometimes employ as they look for clots. Knowing that the highly flexible walls of veins will collapse under even gentle pressure, the technicians press the transducer against the leg or arm to see whether a suspect vein appears to close up. If it doesn't, presumably an unseen clot is keeping it open.

"But it takes a great deal of skill to do this," Pedersen says. "We wondered whether we could automate it. We came up with a method that uses a small plate to apply soft vibrations of different frequencies to the skin while a sensitive ultrasound technique detects the induced changes in the diameter of the blood vessel with an accuracy of five microns."

While initially designed to detect deep-vein thromboses, the system is also able to gather information about the properties (such as stiffness) of blood vessel walls—information that might be useful in diagnosing other vascular diseases, such as aneurisms and atherosclerosis, a condition characterized by fatty deposits on the inside of arteries. "In tests with simulated blood vessels in the lab, we have demonstrated that the system can map out and display an image of a vessel with reduced diameter, with increased stiffness, or containing a partial blockage," Pedersen says.

It is well-known that tumor tissue is generally harder than normal tissue (this is the basis for finding tumors with palpation). For this reason, tumors deform and move differently than other tissues in response to external stimuli like vibrations, Pedersen says. By using this technique to ultrasonically measure tissue movement in response to applied vibrations, it may be easier to detect certain types of tumors with ultrasound.

In related work, Pedersen and Berrios are conducting experiments with blood vessel models to test a corresponding mathematical model being developed by Dalin Tang, assistant professor of mathematical sciences. The model allows the researchers to explore whether abnormalities in any major blood vessel—such as a clot or arterial plaque—will cause characteristic changes in the shape of the pulse. By simulating pulsatile blood flow, Pedersen and Berrios are using ultrasound to measure how the pulse is transmitted along a blood vessel and how the vessel changes in response to the pulse.

Despite the success of ultrasound in medical diagnosis, a great deal is yet to be learned about how the sound pulses emitted by ultrasound transducers are affected as they travel through specific types of tissue. "The ultrasound signal is affected by everything it encounters as it travels through the body," he explains. "Each tissue layer blurs or distorts the wave front. The shape and orientation of a tissue layer and its roughness have a dramatic effect on the energy that ultimately returns to the transducer."

In work he began at Drexel University, Pedersen is trying to unravel these geometric effects. Donald P. Orofino, in his doctoral research, was able to show that it is possible to mathematically predict the effect of the orientation of a smooth reflective surface,

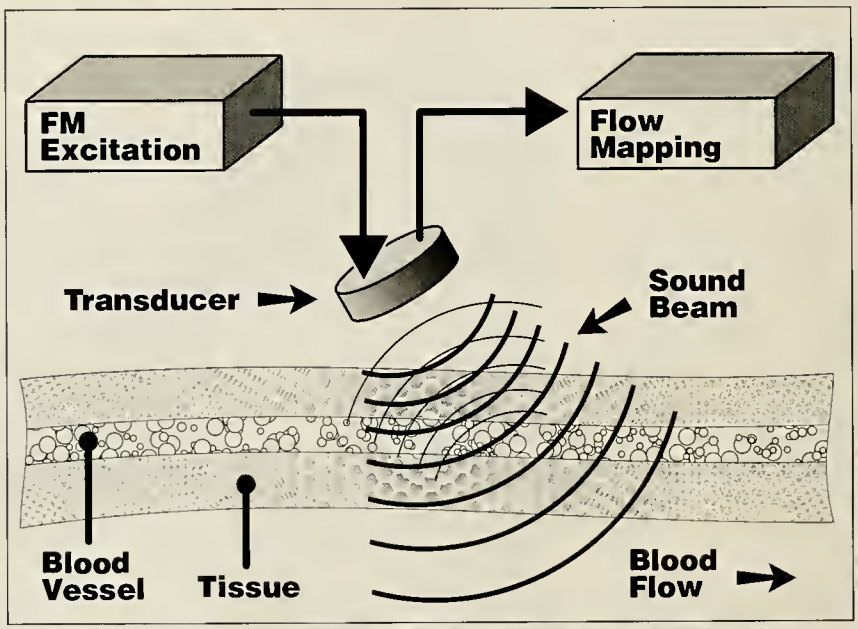


ILLUSTRATION BY MICHAEL SHERMAN

Above, the new Doppler ultrasound system being developed by Peder Pedersen and graduate researchers. The transducer sends out sound in the form of a gliding tone. The sound is reflected from moving blood cells and returned to the transducer. A computer uses the frequency changes in the reflected sound to produce an image of the moving blood. Opposite, Ronald Cheetham and Pamela Weathers examine some of the many clones of genetically transformed *Artemisia annua* plants they have created in the laboratory. *Artemisia* produces an antimalarial compound Cheetham and Weathers hope to extract without harming the plants.

MICHAEL DORSEY

whether a large layer or a small tile. "This was a terrific piece of work," Pedersen says. "But it was just a first step toward understanding all of the mechanisms that affect an ultrasound signal."

Pedersen says he hopes to apply these results to the measurement of the acoustic properties of blood vessels, a more complicated problem because of the way sound backscatters off of the curved surfaces of the vessels. The next major step will be to look at how the roughness of a tissue or organ affects the received signal. Pedersen says he hopes to learn more about rough surface scattering during a sabbatical at the Technical University of Denmark that begins this fall.

Turning Plants Into Pharmaceutical Factories

More than 150 years ago, two French chemists isolated a bitter white powder from the bark of the Cinchona tree. Peruvian Incas had long used an extract of the bark to treat fever, and as early as the early 1600s Jesuit missionaries had discovered that the extract could also cure malaria. The substance the French chemists derived from the bark proved to be the source of the bark's curative powers. They named it quinine, after quina-quina, the Incas' name for the tree.

Quinine quickly became the treatment of choice for preventing and curing malaria. In time, this alkaloid was joined by a host of synthetic antimalarials, created when wars cut nations off from their supply of quinine or when the parasites that cause malaria developed resistance to quinine and other malaria drugs.

While the use of these antimalarials has reduced dramatically the percentage of the world population that suffers from this deadly disease, it still affects some 200 to 300 million people annually, mostly in tropical, newly developing nations, and remains one of the world's biggest killers. Today the search for new antimalarials continues. One promising target is artemisinin, a compound derived from the bitter chinese herb *Artemisia annua,* also called sweet wormwood.

For more than 20 years, Chinese scientists have known that artemisinin is a potent antimalarial with few of the side effects associated with other malaria treatments. Currently, the only way to obtain this compound is to grow *Artemisia annua,* harvest it and then chemically extract artemisinin from the roots and stems, an expensive and wasteful process.

With a three-year, $99,000 grant from the National Institutes of Health, Pamela Weathers, associate professor of biology and biotechnology, and Ronald D. Cheetham, professor of biology and biotechnology, are developing a way of extracting artemisinin from living plants. The method turns the plants into continuously producing artemisinin factories.

The technique involves genetically transforming *Artemisia* with a bacteria that causes fast-growing "hairy roots" to emerge from the plant's own roots. These transformed roots are then grown in culture and various agents are used to induce environmental and chemical stresses that tax the plant and cause the roots to release their artemisinin into the culture media, where it can be recovered and purified.

In earlier work with beets and safflower plants, Weathers and Cheetham showed that this release technique works and leaves the plants unharmed. They have received a United States patent on the process and a second U.S. patent and several international patents are pending.

So far, the researchers, working with research scientist Alex Dilorio and a team of graduate and undergraduate students, have generated a number of transformed clones of *Artemisia* and are evaluating them to see which grow best in culture, which produce the

greatest quantities of artemisinin, and which techniques are most successful in causing the transformed roots to give up the chemical. "The most important factors in this research are growth rates and yields," Cheetham says. "If they're not high enough, you're fighting a losing battle."

If artemisinin is to be successful as a malaria fighter, the researchers note, it will have to be inexpensive enough to be affordable to residents of the Third World. That will mean finding a way to grow the *Artemisia* cultures on a large scale. For that, Weathers and Cheetham plan to turn to aeroponics, a method of growing plants without soil. In an aeroponic system, a fine mist is used to continuously coat the roots with a nutrient-rich film. In the research with beets and safflower, it was found that the plants grew equally well in a nutrient mist system and in nutrient-filled flasks, the method normally used for plant tissue culture.

The advantage of the aeroponic system is that it may be easier to scale up than other culture methods, Weathers says, although the scale-up process will still likely be fraught with challenges. "It looks like a simple technology," she says, "but it's quite complex from a fluids standpoint. The challenge is getting an even distribution of nutrients to a packed bed of roots."

Toward that end, Weathers and Cheetham are working with Douglas B. Walcerz, assistant professor of mechanical engineering, to develop a fluid dynamics model of a proposed aeroponic system to better understand what might happen as the technology is increased in scale. They are also collaborating with researchers at Cornell University and with a New York State plant grower on a space- and water-saving A-frame system that could be used for the large-scale aeroponic production of *Artemisia* and a host of other valuable plants.

The ability to culture *Artemisia* inexpensively may have medical benefits beyond treating malaria, Weathers says. In research over the past decade, other compounds produced by the plant have shown promise as treatments for diseases as diverse as *Pneumocystis carinii*, a prime killer of people infected with AIDS, and schistosomaisis, a severe infection caused by a parasitic flatworm.

At the same time, Weathers and Cheetham are looking to expand their culture and extraction techniques to other plants that produce valuable chemicals. These include *Euphorbia lathyrus,* a member of the spurge family that makes a compound that may repel rats, and the various species of *Taxus* or yews, which manufacture a variety of chemicals with medical applications, including taxol, a proven cancer fighter.

Currently, taxol is obtained by harvesting *Taxus* and extracting the chemical from the bark and needles. It takes 20,000 pounds of bark to make a half pound of taxol. To make the compound more affordable—and more readily available—scientists are trying to find more economical and efficient ways to grow *Taxus* and extract taxol and related compounds.

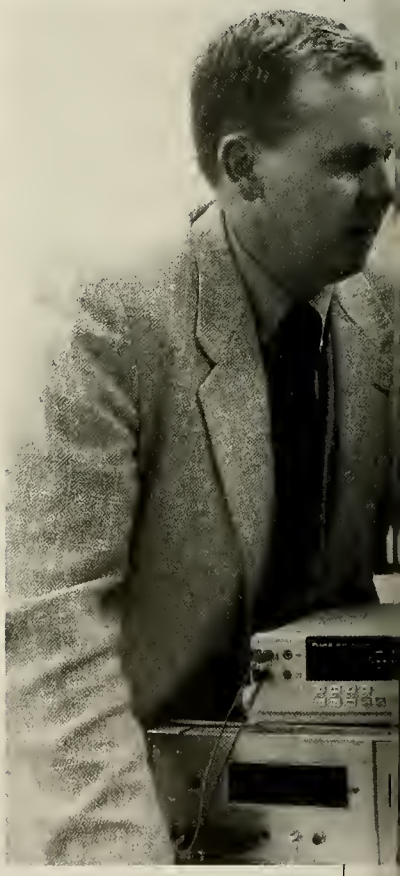
In work done so far in the lab of Weathers and Cheetham, *Taxus* plantlets have been grown aeroponically to study how the roots grow in a nutrient mist. In addition to developing a way of extracting taxol from roots, the research may demonstrate how whole plants can be grown more efficiently in the field. In fact, Weathers and Cheetham are using the expertise they've gained so far to help researchers at Pennsylvania State University, including Laura J. Wagner '90, improve the rooting of a type of fast-maturing *Taxus* plant they have developed.

"With *Taxus,* there are a lot of unknowns," Cheetham says. "Different species of the plant may produce different products in different amounts. Products produced in *Taxus* roots may be different than those produced in the bark and needles. Things that work in the lab, may not work at larger scales. So while we have been seeing small success stories here and there, they may or may not be the routes that lead to commercial production."

New Catheter Will Find and Treat Cardiac Arrhythmias

Millions of Americans suffer from cardiac arrhythmia, a condition characterized by irregular and often inefficient heart pumping. Each year, more than half a million people die from the condition when the arrhythmia causes the heart to begin beating spasmodically, a state known as fibrillation.

In a normal heart, a small mass of tissue in the right atrium called the pacemaker sends out regular electrical pulses that synchronize the contraction of the heart muscle, producing a regular, coordinated beat. But in arrhythmia, a second point in either the right or left ventricle begins generating its own pacemaker signal, which causes the efficiency and output of the heart to drop; in severe cases, the result can be fibrillation.



MICHAEL DORSEY

Current medical procedures for detecting and treating arrhythmias are expensive and highly invasive, notes Robert A. Peura, professor and head of the Biomedical Engineering Department. A commonly used technique involves opening the heart, searching out the source of the aberrant pacemaker signal with an electrical probe, and then destroying it surgically.

With a three-year, $115,000 grant from the National Institutes of Health, Peura and Stevan Kun, a research associate in the Biomedical Engineering Department, are developing a new technology that will enable physicians to locate arrhythmogenic foci and remove them in a minimally invasive manner. The technique will employ a catheter that, when introduced into the right or left ventricle through an artery or vein, will generate a map of the electrical potentials of the inside of the chamber. An arrhythmogenic focus will show up as a disruption in this potential map.

Called the Intraventricular Impedance Imaging Catheter, the device includes eight columns of electrodes arranged on the surface of a small balloon catheter that is inflated once the probe enters the heart cavity. Each column has seven electrodes. Two of them generate a low-magnitude electric field of a high enough frequency so as not to stimulate the heart. The others are used to measure the electrical potential inside the heart. The measured potentials are used to determine the position of the probe.

"We want to be able to precisely locate the arrhythmogenic foci," Peura says. "This is complicated by the fact that the probe moves as the heart beats. To overcome this difficulty, we must continuously measure the position of the catheter with respect to the walls of the heart."

To make this measurement, Peura's team is turning to a technique known as impedance imaging. Impedance is the measure of the apparent resistance to the flow of alternating current. Since blood is far less electrically resistive than heart muscle, the boundary between blood and muscle in the heart creates a discernible change in impedance.

Robert Peura, left, and research associate Stevan Kun use a model to demonstrate how a catheter they are developing will be inserted into a ventricle in the heart. The cathode will use impedance to accurately locate tissue in the ventricle responsible for arrhythmias.

By sending out a current and then measuring this characteristic change, the probe generates data that can be used to produce a continuous three-dimensional geometric approximation of the heart ventricle. Using this image, it should be possible to accurately guide the probe to the spot on the ventricle wall responsible for the second pacemaker signal and then to use a device attached to the catheter to destroy it.

In addition to providing a means to detect and treat arrhythmias, the catheter will provide valuable information about the state of the heart that currently can be obtained in no other way, Peura says. For example, a three-dimensional geometric approximation of the heart can be used to calculate the heart's volume. Adding a pressure transducer to the catheter will permit the generation of a pressure/volume curve, which can provide clues about the condition of the heart muscle. It can also be used to calculate cardiac output and measure the efficiency of the heart.

"Some of these measurements can be made—with limited accuracy—using existing techniques like echocardiography, angiography and radioisotope imaging," Kun says. "But none of these technologies provides continuous, real-time data. And no technique can reliably measure the heart's volume in real time. Our probe will provide an invaluable source of data for clinical diagnosis and can also be used in research on human and animal hearts."

Peura says laboratory experiments with a prototype of the catheter and a simulated ventricle have demonstrated that the basic concepts employed in the device do work. Currently, a team of graduate students is at work further developing the mathematical models of the relationship between the electric field generated by the probe and the conductive properties of blood, muscle and heart tissue. Another student is using such sophisticated computing tools as neural networks to better understand how to use the impedance measurements to approximate the shape of the heart.

Horseshoe Crab Focus of Medically Related Discoveries

For more than a decade, the blood of the horseshoe crab has provided the key ingredient for a standard test of bacterial contamination in injectable drugs. The chemical, known as Limulus Amebocyte Lysate or LAL, becomes a thick, milky gel in the presence of gram-negative bacteria—a class of microorganisms responsible for many human diseases.

To get an adequate supply of LAL, horseshoe crabs, mostly larger females, are captured and bled once a year when they come inshore on the New England coast to mate and feed. While the procedure kills fewer than 1 percent of animals that are bled carefully, more are probably lost in large commercial operations and some scientists worry that the bleeding process may diminish the crabs' reproductive success.

In addition, the sensitivity of LAL produced by different manufacturers—and often within different lots made by the same manufacturer—can vary significantly. This is probably due to differences between crabs and to seasonal and environmental factors that affect blood cell production within crabs.

Daniel G. Gibson III, assistant professor of biology and biotechnology, has spent the past several years developing a technique for culturing the cells that manufacture the horseshoe crab's blood. The procedure would eliminate the need for the yearly bleeding of crabs, assure a more uniform supply of lysate, and prepare for the day when a natural calamity might well decimate the horseshoe crab population.

The first and most challenging step in this process was discovering just where the crab keeps its blood-producing cells. Gibson found a clue to their location in a 12-year-old report that described the presence of significant numbers of blood cells in the flaps of the crab's gill. Since the horseshoe crab does not use its blood cells to carry oxygen, Gibson wondered why they would congregate there.

Under low magnification the interior of the gill flaps appears wrinkled. Upon closer observation, the wrinkles turn out to be a network of pods. It is in and around these pods, Gibson suspected, that the blood cells are created. To test this hypothesis, he removed the flaps and treated them with a disinfectant that caused the blood cells to rupture. Within a week new cells reappeared, clustered

around the pods. In another week, the cells broke free and dispersed. Their source had been found.

The next step was finding a way to culture the pods and recover the blood cells. Master's degree student Joan Hilly paved the way for this breakthrough with her discovery that the gill flaps can be opened with a fine glass needle. The opened flaps can then be cultured in blood serum. As they mature, the amebocytes are tested for their reactivity to endotoxin. The goal of the project is to harvest the cells and extract the LAL, just as it would be extracted from blood drawn from whole crabs.

In 1992, Gibson and Hilly received a U.S. patent for the entire process of preparing and culturing the gill flaps for the purpose of recovering the LAL. Gibson says he envisions a time when colonies of horseshoe crabs might be kept in captivity. By regularly harvesting small portions of their gill flaps (adults have about 1,000 flaps, a few hundred of which can be spared), the crabs could continue to produce a regular supply of LAL for many years.

Ideally, Gibson says, he would like to find a way to make the gill flap cultures immortal, so once started they would produce amebocytes continuously, entirely eliminating the need for the crabs. Currently, the flaps remain productive for only a few weeks, but graduate student Jill A. Friberg is working to transform the amebocyte-producing cells with a virus that may override the natural control mechanism in the cells' DNA that prevents unrestrained cell growth.

In other work, Gibson and Friberg are investigating ways to stimulate the gills to produce greater quantities of amebocytes. Summer research they did at the Marine Biological Laboratory with Jack Levin suggested that extracting blood from crabs has that effect. Levin is a hematologist at the University of California at San Francisco and the co-discoverer of the reaction between LAL and bacterial endotoxins. Injecting crabs with a hormone that triggers molting may also bolster cell counts. "After a crab molts, it increases in size—and volume—dramatically," Gibson says. "It needs to boost its production of blood to compensate. We may be able to use that effect to increase the output of our cell cultures."

As he has worked with horseshoe crabs over the years, Gibson says he has become intrigued with other aspects of their physiology and behavior. For example, he notes, as the crabs get larger, the amount of muscle tissue per unit volume in the animals shrinks. He became curious about how the crabs continue to generate adequate energy to swim and move about on the ocean floor.

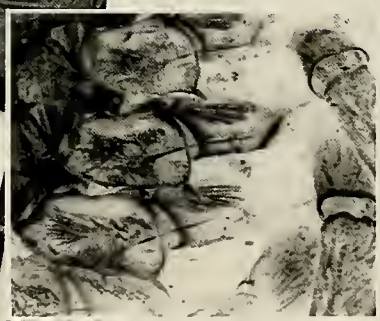
Gibson suspected that each time a crab molts, its muscle fibers gain additional mitochondria—the organelles in cells that are responsible for turning glucose into energy. In other words, the larger the animal becomes, the more biological engines it has powering its muscle fibers. Using an electron microscope to examine and count the mitochondria in muscles from crabs of different ages, he confirmed his hypothesis.

To make sure the differences were not somehow created by the process of preparing and staining the muscle tissue, he is currently examining muscle in living horseshoe crabs with a confocal microscope at the Marine Biological Laboratory in Woods Hole, Mass. A confocal microscope uses special optics and a digital computer to peer though the translucent shell of the crab and reconstruct a detailed, three-dimensional image of its internal organs.

The preliminary results from living crabs also indicate that the mitochondria multiply as the crab ages. Beyond helping to answer this question, Gibson says his work with the confocal microscope may have implications for human medicine. "There are a number of mitochondrial diseases in humans," he says. "In ragged red fiber disease, for example, the muscle fibers begin to look strange after the age of 50 or so. The patient becomes weak and can end up paralyzed."

The problem, Gibson says, can be traced to genetic defects in the muscle mitochondria, which have their own DNA separate from the muscle cell's genome. To improve the diagnosis of this and similar conditions, he says it may be possible to design a fiber-optic probe for a confocal microscope that could be inserted through a small slit in the skin to examine the condition of muscle mitochondria.

JANET WOODCOCK



Graduate student Jill Friberg and Professor Daniel Gibson extract a blood sample from a horseshoe crab. The two are continuing to develop ways to culture the crab's blood producing cells. They are also studying mitochondria in crab muscle with confocal microscopy, a technique that can look through the translucent shell of a living crab (see inset).

GREETINGS from WPI

...wish you were here

Postcards from about 1912 depict Boynton Hall, right, and the Washburn Shops.

For the hundreds of thousands of serious collectors of postcards, 1993 is a special year. It was exactly 100 years ago that the nation's first commercially produced picture postcards appeared. Sold two for a nickel from vending machines, the cards were marketed as souvenirs to visitors at the World's Columbian Exposition in Chicago.

But their lineage is traced to Henrich von Stephan in Germany. In 1865, the year WPI was founded, von Stephan devised the postal card (no picture) as a way to make it easier and cheaper for people to keep in touch. The Austrian government was the first to issue postal cards; the first U.S. cards appeared in 1872.

William Henry Jackson, a mapmaker for the Union Army during the Civil War and a well-traveled explorer and artist, may have made the first true picture postcards—sketches he mailed home

embellished with personal messages. Later, Jackson's photographs of the U.S. were used on a wildly successful series of postcards published by the Detroit Printing Co. starting in the 1890s.

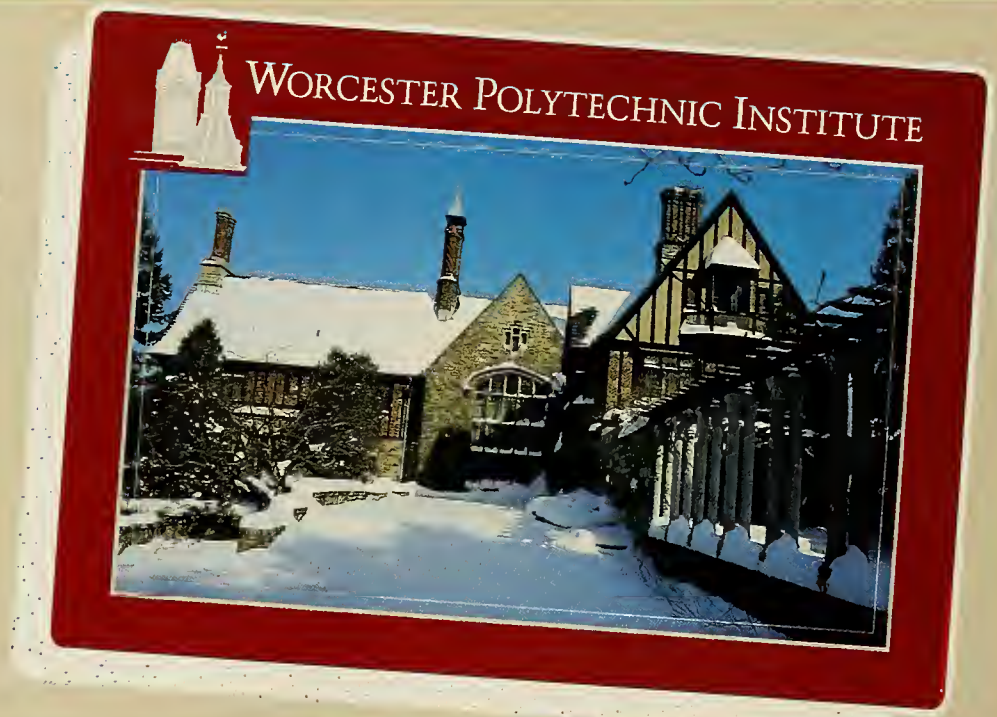
But picture postcards were already coming into their own by the time Jackson's photos first appeared. Early subjects tended to be major exhibitions, like the Paris Exhibition of 1882, where commercially produced picture postcards—depicting the Eiffel Tower—made their world debut.

In the U.S., postcards bearing photographs and other images enjoyed increasing popularity in the years just after the Columbian Exposition. But it took an act of Congress to launch the picture postcard's true "golden age." Until 1898, the federal government maintained a double standard for postcard users. Using a government-printed card to send one's greetings cost Americans 1 cent; but the postage on privately printed cards was 2 cents.

The Private Mailing Card Act of May 19, 1898, established a uniform 1-cent postage rate for all postcards. The act unleashed the nation's pent-up hunger for card collecting, and dozens of postcard publishers sprang up around the nation only too eager to satisfy the demand. In short order, the picture postcard became a ubiquitous part of the American landscape, and deltiology (what some fans call postcard collecting) became a hobby that still rivals philately (stamp collecting) in popularity.

Over the years, it seems virtually every city, state, region, historic site, county fair, landmark, tourist trap, scenic overview, amusement park, motel, restaurant, historic event and famous person has been immortalized on a picture postcard—

Clockwise from top, left, the view from Institute Road in 1906; campus scenes circa 1942; Gordon Library circa 1968; Salisbury Laboratories, date unknown.



Top, Higgins House is the star of this card published in 1988. Bottom, the Institute's most recent postcard, published in 1990.

or a whole series of cards. Collectors divide the vast assortment of such cards into anywhere from 300 to 400 categories.

While WPI might not merit a category all its own, it has issued its share of the popular mailers over the years. The earliest in the collection have postmarks or inscriptions dated 1906. Many of the early cards sport hand-tinted black and white photographs. The Institute's most recent card—which depicts an aerial view of the campus adorned in fall colors—was published in 1990.

On these pages we have presented a small sample of the many postcards that have portrayed views of the WPI campus over the years. Our thanks to WPI archivist Lora Brueck for her help in assembling this collection.

WPI AND THE HEALING ARTS

Here are the stories of 15 alumni who've used their educations as stepping-stones to careers in medicine.

BY DIANE BENISON, CAROL CAMPBELL, ALLISON CHISOLM AND RUTH TRASK

Among WPI's more than 20,000 alumni is a small but growing group who have found their degrees in engineering, science, management and the liberal arts to be ideal preparation for careers in medically related professions. They work today as doctors, nurses, dentists, hospital engineers, public health professionals, medical researchers, administrators of medical facilities, and in many, many other related occupations.

They are fighting the ravages of heart disease and cancer, ministering to the sick and injured in city emergency rooms, treating all manner of health problems and patients as general practitioners and specialists, developing new devices and medical procedures to save lives and improve the delivery of health care, teaching the next generation of physicians in teaching hospitals, and even helping the terminally ill live well until they die.

In the pages that follow, we invite you to meet several of these talented men and women. Their stories were reported by Diane Benison, a former newspaper editor who writes regularly for the *WPI Journal*, Carol Campbell, a free-lance writer from Sturbridge, Mass., who last wrote about manufacturing executives for the *Journal* (Winter 1992), Allison Chisolm, a Worcester-based writer who recently moved to the area from New York City, and Ruth Trask, who recently retired as WPI's alumni news editor, but who plans to continue to delight *Journal* readers with her profiles of alumni.

Knowledge of Technology Helps Athina Kyritsis in Her Training in Pediatrics

Pediatric care can begin before birth and generally ends when the patient turns 19," says Dr. Athina Kyritsis '87, a second-year resident in pediatric medicine at All Children's Hospital in St. Petersburg, Fla. "But it can continue into adulthood when patients have childhood illnesses like cystic fibrosis. In such cases, pediatric medicine has sometimes made discoveries and breakthroughs with which physicians who treat adults may not be familiar."

When tests and diagnostic procedures like sonograms identify medical problems in a developing fetus, pediatricians may become involved in a child's prenatal care, she says. "A pediatrician or neonatologist may be called in to discuss with the parents the likely outcome and prognosis for the child, and what the management might involve."

All Children's Hospital is a "subspecialty hospital that accepts transfers from other hospitals that have patients with complicated cases or who need special attention," Kyritsis says. "We have all the subspecialties of pediatrics at our hospital. As part of the University of South Florida, it is also a teaching hospital, so it carries the highest standard of care."

Kyritsis says doing her undergraduate work at a college known primarily for its engineering and science programs was a help to her in medical school. "It's good to go into medicine with a background in engineering or anything that introduces you to technology, because medical diagnosis is now so technologically advanced; it takes quite a bit of understanding to be able to apply that technology to clinical practice.

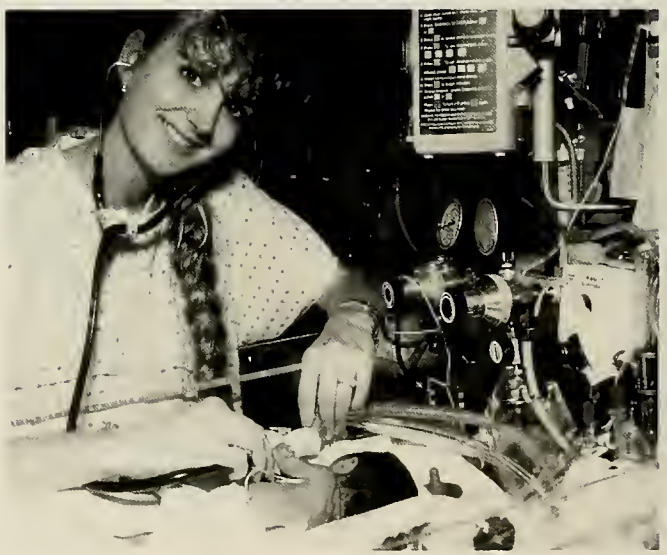
"The breakthroughs happening in medicine are extraordinary. A thorough grounding in technology helps you understand how the diagnostic studies are done and the implications of the methodologies. Then you can apply that understanding to your own diagnosis. It's also helpful to know how medical technology like MRI or CT scanners work so you can understand their limitations."

Despite her technical background, Kyritsis says she found medical school "initially overwhelming. It was like being given a spoon to scoop out the ocean. It's overwhelming how much information you're expected to learn in a short period of time. It seems beyond your capacity to do so, then all of a sudden you find that you're able to do it.

"Just when you think you can't possibly make room for more information, your second year starts and your work load doubles. You really think that you're likely to lose your mind. But somehow you find you can do it. With some sacrifice and some perseverance you get through it. In the third year you're introduced to clinical sciences and you realize that what you've read in books didn't tell you all you need to know to diagnose patients. You start to develop your diagnostic skills and your physical exam skills.

"Then you're thrown into residency. That's unbelievable. All of a sudden you're responsible for patients. You're on call, so most of the time you're exhausted. You're constantly second-guessing your decisions and you're hoping you've done the right thing. You're hoping you've had good communications and interaction with the patient and the family, since you are the critical link between them and the illness. It's a scary time, but your confidence builds and it's not so overwhelming anymore—finally."

Part of what makes residency so overwhelming are the 36-hour shifts a resident must endure every four days. Kyritsis says she accepts this on-call duty as part of the rite of passage in a doctor's training. But, she adds, "it's difficult when you get home at night and you have a baby and a husband and a house and you haven't slept. You need to prioritize the little time that you have while your eyes are still open."



KEVIN PRICE

She and her husband, Dr. Zannos Grekos, who is doing a fellowship in cardiology, have a 14-month-old daughter and a second child due in January. Any doubts about her powers of organization are dispelled by the offhand comment that she breastfed her daughter during her first year of residency.

Like some other WPI Plan graduates, Kyritsis had trouble getting medical schools to accept her WPI grades. The University of South Florida Medical School in Tampa accepted her, but required her to take a course of its choice at the university before she started. The course was comparable to one she'd taken at WPI; after doing extremely well on the first two tests, she was excused from finishing it. "I guess they saw that the standard of education at WPI was more than adequate.

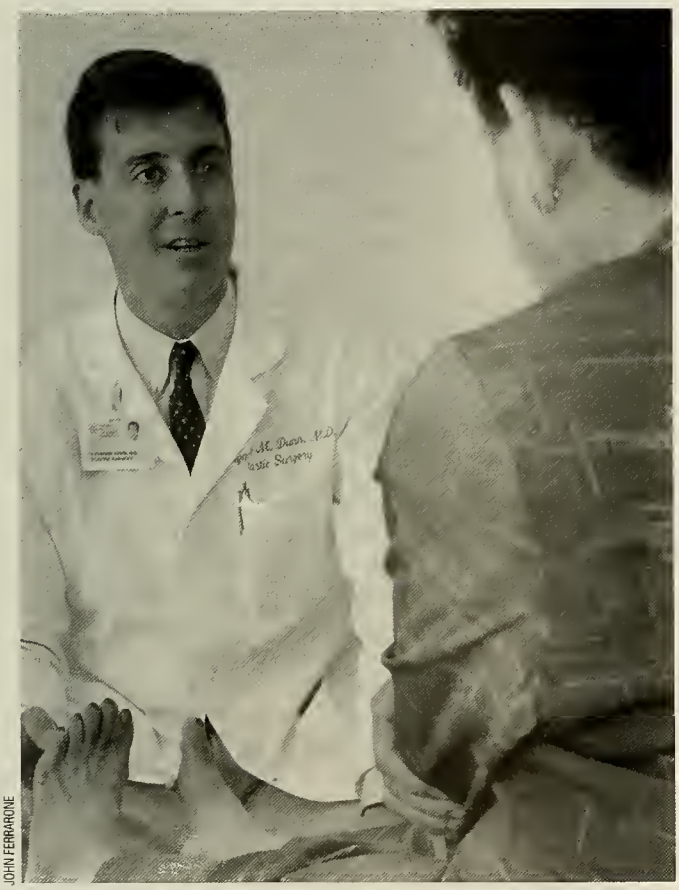
"I really enjoy what I do. I like pediatrics. I like medicine. I recommend medicine to anyone who would like a career that has a tremendous interaction with people and is intellectually challenging."

—Diane Benison

RAYMOND DUNN GIVES LEG ULCER SUFFERERS A NEW LEASE ON LIFE

About 2 million Americans—young and old—suffer from chronic leg ulcers caused by venous insufficiency. The ulcers, which typically appear on the inside of the leg near the ankle, are unpleasant, unsightly and painful and can make it difficult to lead a normal, active life.

Chronic venous ulcers are the final stage of a process that begins with the formation of a blood clot in veins of the leg. The clot, which can form for a number of reasons, including injuries and pregnancy, often grows to engulf one of more of the valves inside the vein that



JOHN FERRARONE

help blood to flow back to the heart. In time, the body dissolves the clot, but in the process the valves are often damaged or destroyed.

Without the valves to keep it moving, blood pools in the vein, a condition known as venous stasis. Over a period of time, the blood may seep out into the surrounding tissue. As they diffuse through the tissue of the leg, blood cells die, releasing compounds that damage the tissue. For many people with this condition, that tissue damage leads to leg ulcers.

For some 3,000 years, the treatment of choice for leg ulcers has been elevating the leg above the heart. Over the course of weeks, the pooled blood flows out of the vein and the ulcer usually recedes. But this is only a temporary solution, since the ulcers often return once activity is resumed, and prolonged bed rest—up to three months—is often impractical for younger patients. Surgical solutions, including vein repairs and skin grafts, can bring about relief, but too often these procedures also fail to provide a permanent cure.

According to Dr. Raymond M. Dunn '78, assistant professor of plastic surgery and clinical director of the Plastic Surgery Research Laboratories at the University of Massachusetts Medical Center, the lack of an adequate treatment for leg ulcers may be due, in part, to the fact that the condition is not typically life threatening. In addition, it affects sections of the body that fall with the province of three different medical specialties.

"Ulcers and wounds fall under plastic surgery," he says. "Veins and arteries are the domain of vascular surgery. And skin problems are covered by dermatology. This problem has gotten lost somewhere in between. A vascular surgeon will think about how he can fix the veins; a dermatologist will treat the skin; a plastic surgeon will deal with the wound. The problem is truly interdisciplinary."

It was during his medical training that Dunn says he first got an insight into how an effective treatment for leg ulcers might be developed. His inspiration came when treating a young patient at a Veterans Administration hospital in Virginia. "He had had a leg ulcer and, for no good reason, a plastic surgeon had done a microsurgical flap procedure on him," Dunn says. "I asked him how the leg was doing, and he made a statement that turned a light bulb on in my head. He said, 'When I get a scratch or a bruise on the area with my flap, it heals just like normal.'"

When leg ulcers are treated with skin grafts—a common approach, Dunn says—scratches and bruises may cause the ulceration to reappear. But for some reason, the skin flap had held up well to normal wear and tear. "That's where my interest in this procedure began," he says.

Unlike a graft, where only the skin is removed and transplanted to the area affected by the ulcer, microsurgical flap surgery involves also taking the tissue underlying the skin—including arteries and veins. In the surgical application Dunn pioneered, a flap is removed from the back and attached to the area from which the ulcer has been removed. The blood vessels in the flap are then painstakingly hooked up to the leg's own vasculature.

As Dunn and his colleagues at UMass studied the results of the procedures they performed, they were surprised to find that the veins in the flaps they transplanted from their patients backs contained numerous small valves. "No one had ever reported seeing valves in these veins," he says. "We're not sure why they are there, since blood in the back veins flows down—with the force of gravity—toward the heart.

"With this operation," Dunn adds, "we are able to address all of the problems that contribute to leg ulcers. In one procedure, we transplant valves, we graft skin and we remove the scarred wound." Dunn has performed 10 flap procedures for leg ulcer sufferers. To date, none of the ulcers has reappeared.

Dunn says the procedure has met with some skepticism in the medical community, particularly from vascular surgeons who are puzzled by how the procedure can be effective if the original source of the ulcer—the damaged vein—is not repaired. Dunn says more research needs to be done to fully understand why the technique works, but he notes that its success may indicate that the cause of leg ulcers is more complicated than previously thought.

"With this operation, we are able to address all of the problems that contribute to leg ulcers. In one procedure, we transplant valves, we graft skin and we remove the scarred wound."

Dunn, along with a vascular surgeon and a dermatologist, sees patients with leg ulcers and other vascular diseases in the Venous Clinic they founded at the UMass Medical Center. The clinic is the only one of its kind in New England. "Actually," Dunn says, "we don't know of any other center in the country that has brought these three disciplines together to address this problem."

Dunn, who received his bachelor's degree in chemistry from WPI, earned his M.D. at Albany (N.Y.) Medical College in 1982. "Early in my education, it became apparent to me that I was interested in surgery," he says. "No doubt my strong engineering orientation as a WPI student predisposed me to this inclination."

He undertook his residency in general surgery at UMass in 1982 and was board certified in that discipline in 1988. In 1987, he began his training in plastic surgery at the Eastern Virginia Medical Center in Norfolk, completing the program in 1990. He says he was attracted to plastic surgery because it enables a practitioner to put the principles of surgery to work on a constantly changing array of surgical challenges.

"In many surgical disciplines, doctors learn a set of operations that they perform over and over again," he notes. "The plastic surgeon's task is different with each patient. Doing this type of work involves a lot of problem solving, and that's a lot like engineering. I honestly believe the education I received in engineering at WPI has made me a better practitioner, because problem solving is really what medicine is all about."

During his stay in Virginia, Dunn traveled to West Africa, the Philippines and Turkey, where he worked with volunteer surgical organizations from the Norfolk area providing care for children with burns and congenital defects, such as cleft lips. "That was a particularly gratifying part of my training, which I hope to continue throughout my career," he says. Today he is a surgical volunteer with the Federico Trillo Foundation in San Juan, Puerto Rico.

A Maimonides Fellowship, which he received during his training program in Virginia, enabled him to travel throughout Israel to observe plastic surgery at various universities. The fellowship is given each year to one resident in plastic surgery in Virginia.

While in Virginia he also received the Burroughs-Welcome Resident Leadership Award from the American Medical Association for his voluntary surgical activities and was appointed a resident delegate to the American Medical Association by the American Society of Plastic and Reconstructive Surgery, which enabled him to participate in national forums on medicine. Basic research he performed in Virginia resulted in a paper on microsurgical monitoring, which earned him the Best Paper Award from the Plastic Surgery Education Foundation in 1990.

Dunn began his full-time practice in plastic and reconstructive surgery at UMass in 1990. He says the bulk of his time in the operating room is spent in reconstructive surgery. In addition to his work with patients, Dunn also spends time teaching and mentoring medical students at the university.

As an affiliate assistant professor of biomedical engineering at WPI, he advises undergraduates completing MQPs and master's degree candidates on a variety of research projects at UMass. And, he is a member of WPI's Pre-Health Professions Advisory Committee, which helps to improve opportunities for undergraduates who aspire to medical careers.

His busy life also includes raising 18-month-old triplets—Katie, Meaghan and Sarah—with his wife, Beth. Still, Dunn has found time to become active in the national medical community. A member of the American Association of Clinical Anatomy, the American College of Surgeons and the Massachusetts Society of Plastic Surgery, he is a delegate representing plastic surgery in the Young Physicians Section of the American Medical Association and chairman of the Young Physicians Section for plastic surgery of the American Society for Plastic and Reconstructive Surgery.

"I find this work exciting," he says, "because there are an incredible number of changes coming along in medicine. We will have to find ways in this country to deal with our inability to provide care for everyone. My generation will not only be affected by these changes, but will be involved in the evolution of medicine."

Dunn says one of the goals of his fellow young plastic surgeons is to better educate Americans about what this specialty is all about and to dispell the myth that all plastic surgery consists of face lifts, breast implants and other cosmetic procedures. "People don't have any idea of the breadth of what we do," he says. "We take care of trauma patients and cancer patients. We correct congenital defects. We do surgery of the hand. We do laser surgery, and so on. More than 80 percent of our work is reconstructive surgery. It's really a diverse and exciting field."

—MICHAEL DORSEY AND RUTH TRASK

To Otologic Surgeon Daniel Pender, the Ear Is a Marvelous Mechanical Device

When Dr. Daniel Pender '63 was a mechanical engineering major at the Institute, he never imagined that his future career would find him applying the principles he learned in his engineering courses to the study of the human body. That, however, is precisely how he views his work today as an otologic, or ear, surgeon at the New York Ear Institute and at Columbia Presbyterian Hospital in New York City.

"Otology is a wonderful specialty for a mechanical engineer," he says. "As an ear surgeon, I work on the mechanical structure of the ear. Surgery in that area is interesting—and meticulous. I like meticulous things. Usually that means small, neat machines where you can appreciate how things fit together and work."

Pender says repair of the middle ear requires an understanding of middle- and inner-ear biophysics, impedance or resistance matching, and electrophysiology. He says the ear is essentially an electromechanical device, "a black box that transfers signals in an elaborate way to the brain."

Sound energy arriving in the ear vibrates the eardrum. This movement is transferred, via the linkage formed by the three bones of the middle ear, to a membrane in the cochlea, creating pressure waves in this fluid-filled organ. Receptor cells in the cochlea respond to these waves, converting the various frequencies of sound into electrical signals that travel to the brain along the auditory nerve.

Pender did not always intend to pursue a career in ear surgery. Originally, he says, he was interested in plastic surgery, but was deterred by what he calls "the credentials obstacle. This would require five full years of surgery, which did not interest me," he says. Instead, he chose an ear, nose and throat specialty that he further limited to otology.

After receiving his undergraduate degree from WPI, Pender moved on to the Yale Graduate School of Engineering to work toward a Ph.D in mechanical engineering. After completing one year there and earning his master's, he received a mailing about a summer program at the University of California's Lawrence Radiation Laboratory. Enticed by the idea of spending a summer on the West Coast, he applied. That summer, he moved to California to work full time at the radiation lab.

He later enrolled at the University of Pennsylvania Medical School to complete his M.D. degree. He did his surgical residency at the University of Vermont and completed a two-year research fellowship at Harvard. At Harvard, he studied a drug used in the treatment of Meniere's Syndrome, which causes hearing loss and acute dizziness. The study was published in the *American Journal of Otolaryngology.*

Pender has continued his interest in applied research as a practicing surgeon. One of the products of that work is a device he calls a laser-oto-injecto-scope. The patented apparatus is designed to treat a condition called serious otitis media, a common and persistent ear infection—mostly in children—caused by a build-up of fluid in the middle ear. Pender says the procedure often used to correct the condition—inserting a small drainage tube into the eardrum—is the most commonly performed minor operation in the United States.

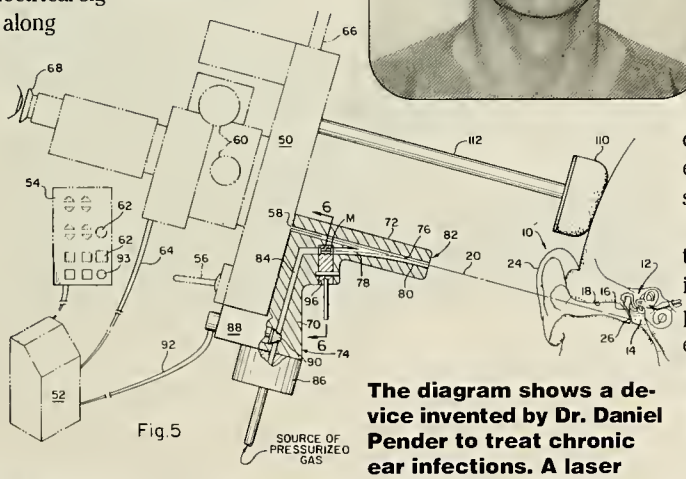
Lasers have been used experimentally to make drainage holes in the human eardrum, but the technique has failed to gain widespread acceptance because of the difficulty of keeping the resulting hole open long enough to drain the fluid. Pender's device solves this problem.

After a topical anesthetic is applied to the eardrum, the laser-oto-injecto-scope is inserted into the ear canal, enabling the physician to sight the proper spot on the eardrum. The device emits a laser pulse and a small, conical grommet. Like a dart shot from a blowgun, the hollow grommet is impelled by a puff of air.

Traveling at the speed of light, the laser pulse opens a small hole in the tissue of the eardrum; a fraction of a second later, the grommet is embedded in the hole to form a drainage tube. The simple, quick procedure can be performed in a doctor's office, Pender says, whereas existing procedures are normally performed in a hospital setting and require general anesthesia.

Pender is in the process of seeking funds to have a prototype built. He said he has recently contacted several venture capital groups. "I'm looking for only $100,000," he says with a laugh, "but some of these groups don't give out less than a million. Any interested investor is welcome to call me."

—Carol Campbell



The diagram shows a device invented by Dr. Daniel Pender to treat chronic ear infections. A laser opens a small hole in the eardrum into which a drainage tube is impelled.

Dentist David Crimmins Benefits from Background in Materials

"Being a dentist was the farthest thing from my mind while I was studying chemistry at WPI," says Dr. David S. Crimmins '58, who has a private practice in Wilbraham, Mass. "But when you get right down to it, it came about naturally, though in a roundabout way."

After earning his undergraduate degree at WPI, Crimmins set out on an educational marathon that continues today. He did graduate work in physical chemistry at the University of Wisconsin and earned his doctor of science degree in metallurgy at MIT. He would later take courses in electrical engineering at the University of Hartford and earn a doctor of dental medicine degree at the University of Pennsylvania School of Dental Medicine.

After MIT, Crimmins served in the U.S. Army Signal Corps as the post signal officer at the Watertown, Mass., Arsenal and as a research metallurgist at the Army's materials lab in Watertown. In 1965 he took a post as a research metallurgist at Du Pont's Engineering Materials Laboratory at the Experimental Station in Wilmington, Del.

A year later he accepted an appointment as an assistant professor in the Biological Materials Department at Northwestern University Dental School and soon moved on to the Department of Metallurgy at the University of Denver. While in Denver, he also taught dental biomaterials two days a week at the UCLA Dental School, commuting over the Rockies on Monday mornings and heading "back over the bump" on Tuesday evenings.

MICHAEL DORSEY

At Northwestern, he taught courses in medical and dental materials, emphasizing the problems encountered in using materials like metals, ceramics, polymers and composites in the biological environment of the human body. At Denver, his teaching focused on physical metallurgy, the physical chemistry of polymer solutions, biomedical materials, and the surface chemistry of materials. He also organized a conference on biomedical materials.

Early in his career, Crimmins left academia to begin a wide-ranging tour through industrial laboratories. He worked first as research manager for Emhart Corp. in Bloomfield, Conn. In 1969 he joined the Military Arms Division of Colt Industries in Hartford, where he was manager of the Advanced Manufacturing Engineering Department in charge of manufacturing planning, facility engineering, cost analysis and manufacturing technology.

He also supervised manufacturing engineers working on advanced projects related to the production of the M-16 rifle and the company's new products. In 1971 he provided engineering assistance and developed training programs in materials and manufacturing as Colt prepared to begin manufacturing the M-16 in Korea.

Crimmins next served two years as manager of manufacturing and product development for the Smith Kline Surgical Specialties Department of Smith Kline & French Laboratories in Philadelphia. He was responsible for the development and marketing of advanced surgical implants and instruments. "I went from one extreme to the other," he says with a smile. "I guess I don't feel comfortable with the 'killing stuff.'

"By 1973, I decided I wanted to get into a more personal, hands-on type of career," Crimmins says. After earning his dental degree, he opened his own practice in Wilbraham. Unlike most dentists, Crimmins brought to his practice an extensive background in metallurgy and in the types of advanced materials that were already beginning to impact the way dentists approach their work.

That background can be seen in the articles Crimmins has authored and co-authored in scientific journals. They include "The Selection and Use of Materials in Surgical Implants," "The Electrochemical Properties of Dental Amalgam," "Mechanical Properties of Stress Relief of Stainless Steel Orthodontic Wire," and "An Apparatus for *In Vitro* Corrosion Testing of Biological Materials."

Crimmins says the education in engineering and chemistry he received at WPI has been helpful at each stage of his career. Today, he notes, he takes a chemist's point of view when it comes to deciding what should and should not go into the human mouth. "Toxicology is a timely topic in dentistry these days," he says. "For example, it's important not to subject patients to reactive materials that can cause deleterious effects on the body."

Crimmins says he is looking beyond private-practice dentistry to yet another career. "I'm interested in working in the area of public health," he says. In fact, in 1992 he completed a master's degree program in public health at the University of Massachusetts at Amherst.

His ultimate goal, he says, is to work in the public health area for the United Nations or the World Health Organization. "I'm studying German, Russian and Mandarin Chinese so I can be as effective as possible, wherever I'm assigned to serve. I'm looking forward to the challenge."

—Ruth Trask

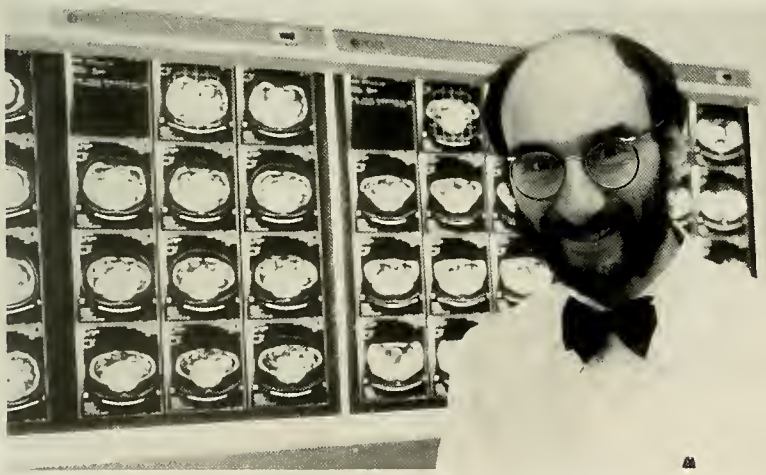
Persistence Helped Bruce Minsky Overcome Obstacles on the Road to Becoming a Successful Oncologist

Maybe it was the experience of being one of the only Jewish students at a Catholic high school in Lawrence, Mass., that nurtured in Dr. Bruce Minsky '77 a tendency to value the nontraditional and to persist against the odds. Today, as a successful physician at Memorial Sloan-Kettering Cancer Center in New York City, he says he values those qualities in himself and laughs at the memories of the problems he encountered on his way to becoming a doctor.

A late bloomer, Minsky did poorly during his first three years of high school. "I didn't really care about academics," he says. "I was busy growing up. The last year I got serious." He decided WPI might be just the place for him to start down the road to becoming a doctor, something he had long dreamed of. "I fought hard to get in," he says. "It didn't come on a silver platter."

The Institute rejected Minsky's application. In those early days of the WPI Plan, the college had an option called negotiated admissions that allowed a rejected applicant to press his case. Minsky went back for a second interview and was accepted with the warning that half of students admitted under negotiated admissions ultimately flunked out. "I did well," he says. "I realized that I flourish where I have a lot of freedom and where I must be self-motivated. Very few institutions offer students that opportunity."

Minsky says one of the most valuable parts of his WPI education was the opportunity to do independent research. He completed his Interactive Qualifying Project and Major Qualifying Project in the biochemistry laboratory at the University of Massachusetts Medical Center. "It was a good experience; I ended up publishing two papers," he says. "I think that helped me immensely in getting into medical school. Usually colleges don't allow undergraduates to spend two years doing major research projects."



In 1977, Minsky hit another roadblock when medical schools denied him admission because of confusion over WPI's unusual grading system. Instead of A's, B's and C's, the Institute then awarded grades of Acceptable (AC) and Acceptable With Distinction (AD). But medical schools wouldn't accept his AD's as A's—despite an explanatory letter from Dean John van Alstyne—making his grade point average too low to meet their requirements. "It was very frustrating," he says.

After a year spent working in the biochemistry department at the University of Massachusetts Medical Center and in the pathology department at Boston University, he reapplied to medical school and was admitted to the UMass Medical School. By that time, the medical school admission system had accepted the value of WPI's AD grade.

At Sloan-Kettering, where he's been since 1986, Minsky divides his time among three functions. In his clinical practice in radiation oncology, he specializes in gastrointestinal cancer. He conducts clinical research in the development of new treatment protocols for patients and basic laboratory research in magnetic resonance spectroscopy. He also directs the residency program for the Department of Radiation Oncology, supervising the training of about 17 residents and fellows each year.

He says he likes all three components of his job equally. "I couldn't live without any of them. I couldn't do any one of them full time. I couldn't practice full time because it would be emotionally overwhelming. I couldn't just do research full time because I would miss the patient care. And it's a lot of fun to train good residents. That's sort of a payback for me."

His research on new cancer treatments focuses on rectal and esophageal cancer. The goal is to find the optimal amounts and sequence of radiation, chemotherapy and surgery to improve a patient's life expectancy and quality of life. He says a significant measure of quality of life is the preservation of a patient's own organs. For people with rectal cancer, for example, that can mean avoiding a colostomy.

Minsky's lab develops the initial clinical trails at Sloan-Kettering and runs them there. Successful trials then move to the national level. He is currently running three national trials of 600 to 1,000 patients each. Funded by the National Cancer Institute, two of the trials are looking at protocols for esophageal cancer and one is studying the treatment of rectal cancer.

Minsky says he became interested in oncology through laboratory research—beginning with his MQP at WPI. "I later found that clinically it was very rewarding to help people with cancer," he says. "I decided that I was going to go into that specialty when I went to medical school."

—Diane Benison

Allison Nunn Enjoys the Challenges and Rewards of Being a Part-time Critical Care Nurse

It was 1985. A full-time mother of three young children, Allison Huse Nunn '73 was considering getting back into the work force. She had worked for four years as a research chemist after graduating from WPI, but had taken a break to start her family. For the previous six years, she and her family had lived in the Pacific Northwest, where her husband, Bruce, also a 1973 WPI grad, worked in the pulp and paper industry.

Knowing the likelihood that Bruce's work might require another move, she decided to go back to school and become a registered nurse, something she says had been in the back of her mind for years. "I wanted to be able to work wherever Bruce's work took us," she says. "Although we lived right near Seattle, where I could get a job in the biochemical field, my fear was that we would end up in the backwoods someplace, where many paper mills are, and there wouldn't be any research jobs.

"Also, I had discovered that I'm more of a people person than I had thought. I had never considered myself a people person—I'd thought of myself as a loner. Three kids will change you."

Nunn says the interests that led to her choice of a career in nursing were kindled at WPI. Having been accepted by MIT and the Institute by the time she graduated from high school in Skaneateles, N.Y., she enrolled at WPI to become a chemist. But after four semesters of calculus, she decided to develop an interdisciplinary science major instead.

"I had taken pharmacology and biochemistry and decided that I really liked those subjects," she says. Her new major enabled her to continue to study chemistry without taking more calculus—a prospect she found appealing. She also focused more of her course work on the life sciences, which led her to develop an incipient interest in medicine.

Nunn enrolled at Tacoma Community College School of Nursing in 1985 and received her associate's degree two years later. While nursing school included some subjects she hadn't taken at WPI, including sociology and psychology, she says her WPI education helped her complete some parts of the curriculum far more quickly than her classmates.

"I finished one required self-study math class in five days; it was supposed to be a normal, semester-long class," says Nunn, who finished nursing school with a 4.0 grade point average. "I found the education I had at WPI made a big difference. Among other things, I already knew how to buckle down and study and pay attention in class."

As a student, she spent six months working as a "monitor tech," interpreting various cardiac monitors in a critical care ward. "Cardiac monitor alarms aren't 100 percent foolproof," she says. "Our job was to make sure the nurses were alerted when there was a real problem."

After graduation she worked as a critical care nurse at a community hospital in Puyallup, starting out full time but soon switching to part-time status. After moving to Spokane in 1988, she worked for a year in the recovery room of the city's largest hospital. She then became a part-time critical care nurse at Holy Family Hospital in Spokane, a 300-bed facility with a 10-bed combined intensive care and coronary care unit.

"We say we live on adrenaline rushes," she says. "In all honesty there are very few of those, but when they come, they come big time. I enjoy the challenge." The real challenge, she is quick to add, is understanding how a patient on multiple medications is being affected by an individual drug or the combination of those drugs.

"We have really sick patients who are frequently on ventilators, multiple monitors and multiple medications simultaneously," she says. "We have to know the drugs, know the reactions those drugs can cause, and know how they react in combination.

"We have to be sure we're aware of how a patient is affected. We are given guidelines by the doctors and we can individualize treatment to the patients' needs without having to call the doctors in many cases. We have to know enough so we can react quickly in a crisis. We have to think about whether one medication is masking something else and about how diminishing or increasing a drug is going to affect a patient's various systems. We feel we can make a real difference to a lot of the patients we care for. It's much more intellectually stimulating than many other parts of nursing."

Nunn says she's pleased she was able to find a way to rejoin the work force and continue to be a nearly full-time mom. She says she also enjoys the sense of responsibility her job gives her. "Critical care nurses have historically been treated with a lot of respect by doctors," she says. "They recognize that we're with the patients many more hours than they are and, therefore, that we can see things that they can't."

—Diane Benison

Bruce Haffty's Scalpel is a Thin Beam of Radiation

Bruce Haffty '76 is used to having his name appear in the national spotlight. As a graduate student at WPI, he was the subject of a feature story in a national publication that described a portable recording system he and research partner Peter W. Kotilainen '74 designed to monitor heart functions during normal activity. Today, his research on breast cancer, biomedical engineering and clinical radiotherapy often draws the attention of publications like *USA Today* and *Prevention*.

Haffty is a radiation oncologist at Yale-New Haven Hospital in New Haven, Conn., where he also serves as associate professor of therapeutic radiology at the Yale University School of Medicine and director of residency in the radiation therapy program. A radiation oncologist is a physician who evaluates cancer patients to see whether and what type of radiation treatment may be appropriate for them. He then delivers that treatment, when needed.

Haffty, right, and colleague Dr. Alain C.J. de Lotbinière, look over magnetic resonance images of a patient to determine a suitable course of radiation treatment.

Haffty has become well known in the medical community for his research on cancers of the breast, brain, and head and neck, and for his work on the lumpectomy in combination with radiation instead of the more extensive mastectomy in treating breast cancer.

For the last year and a half, Haffty has been performing an advanced procedure called stereotactic radiosurgery at Yale-New Haven's Hunter Radiation Therapy Center. The procedure uses a linear accelerator to deliver a narrow beam of high-energy photons to the brain to destroy specific areas of tissue, leaving surrounding regions virtually unaffected.

Stereotactic radiosurgery is used to treat various types of brain tumors, as well as tumors that reside in and around the skull, tumors of the meninges (the membranes surrounding the brain and spinal cord), and tumors of the pituitary gland, among other conditions. The linear accelerator is able to rotate around the patient's head, making it possible to precisely aim the beam and control the dose of radiation delivered to the target site, Haffty says.

Though the procedure was conceived more than 40 years ago by a Swedish neurosurgeon and scientist, neurosurgeons and radiation oncologists have taken a significant interest in it only within the past few years. Haffty says the sophisticated radiation delivery and computer imaging technology available today have finally made this type of surgery feasible and cost effective.

"I went into the field of radiation oncology because of its technological bent—it's very heavy into physics and engineering," says Haffty, who completed a master's degree at WPI in biomedical engineering. As a graduate student, he did research at Saint Vincent Hospital in Worcester on biomedical applications in cardiology and cardiovascular hemodynamics. As part of the research, he studied the feasibility of passing electrical currents through the body to measure blood flow. The results of the work were published in the *Journal of Applied Physiology* and *Chest*, among other journals.

After earning his master's degree, Haffty attended Yale University School of Medicine, completed his internship in internal medicine at Yale-New Haven Hospital, and trained in radiation oncology at the Yale medical school. Today, as director of the residency program in radiation therapy, he is responsible for the training given to six radiation residents.

He is also engaged in research aimed at evaluating a new drug called Porfiromycin, which is used as an adjunct to radiation in the treatment of cancers of the head and neck. Yale-New Haven is currently the only hospital in the world to have a supply of this drug. While the compound is actively being tested on patients, Haffty says it is too early to determine its success.

Despite the time he devotes to research, teaching, writing, conference presentations, and speaking engagements that have taken him as far away as Italy and Venezuela, he says he manages to spend about 70 percent of his time treating patients. "I enjoy the patient interaction," he says. "I see the service I give to patients as very rewarding."

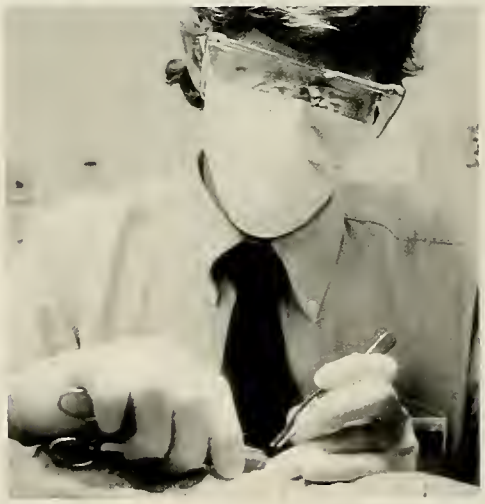
—Carol Campbell

Mark Mahoney Enjoys the Rewards of the High-Stress World of Emergency Medicine

Dr. Mark Mahoney '74 used to open his local newspaper and head straight for the sports section. Now he skips past sports and reads the obituaries first. An emergency room physician, he says he wants to see "if anyone I treated went home and came back dead."

Mahoney is a six-year veteran of the Emergency Department at St. Luke's Hospital in New Bedford, Mass., the state's third busiest. When he started there full time in 1987, he says he might have dealt with one or two trauma cases—car crashes, shootings or stabbings—a week. Now he sees one or two a night.

"This has become a more violent place," he says. "A lot of these cases are probably drug related. New Bedford is an old fishing and seaport town struggling with high unemployment." Because St. Luke's is the area's only large hospital, he adds, "we don't have the luxury of diverting patients. We take all comers."



During his typical 12-hour shifts in the ER, he sees "everything," he says. His work runs the gamut from walk-in patients with colds or sprains to people with recurring illnesses. Summer, with its boating accidents, bee stings, heat stokes, fireworks injuries, and other seasonal emergencies, is the busiest time of year. In a 24-hour period during warm weather, he and another staff doctor are likely to see 150 to 180 cases.

Mahoney has not spent his entire career as an emergency room doctor. After completing his medical training, he opened a family practice in Mattapoisett, Mass., in 1981. He also took a 24-hour shift twice a week as the head of an area emergency room. Six years ago, he decided those marathon nights on call were too much, even for a doctor who enjoys distance running in his off hours. When his practice started to generate more paperwork than patient care, he decided the time had come for a change.

His hours in the ER had qualified him to take the Emergency Medicine board exams, so in 1987 he gave up the family practice and moved full time into emergency medicine at St. Luke's. Responding to health emergencies became for Mahoney the foundation of a satisfying career with surprisingly predictable hours.

"Once you're home, you're off," he says, noting that his set schedule, which places him on call only occasionally, "gives me better hours and more time to relax." He can also spend more time with his wife, Kathryn, a veteran marathon runner, and three boys, ages 10, 11 and 13. Still, he admits, it can take a few hours to unwind from the pressures of emergency room work. "If I work until midnight or 2 a.m., I might not get to sleep until 3 or 4 a.m.," he says.

PHOTOS BY JANET WOODCOCK

Mahoney's arrival in medicine was, as he describes it, a case of "serendipity." An organic chemistry major at WPI, he was considering biochemistry positions in California when a friend told him he was planning to take the MCAT, the entrance exam for medical schools. "I went along with him and did all right," Mahoney recalls with a nonchalance unknown to most pre-med students. "It wasn't something I had planned ahead for."

He landed at the University of Connecticut Medical School in Farmington, 10 miles from his home in New Britain, Conn. He says his WPI education gave him a good grounding for his first two years of basic science courses. After another two years in clinical rotations, Mahoney arrived in Abington, Penn., for a three-year family practice residency.

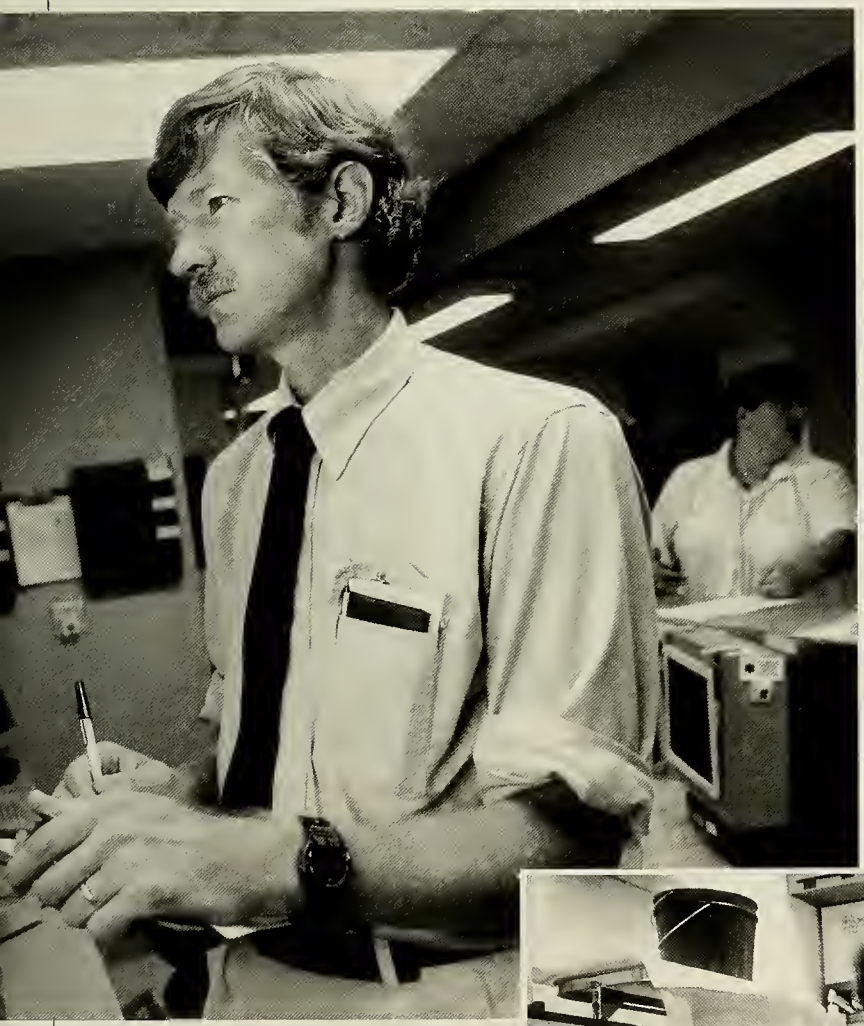
Now, after 12 years in emergency medicine, Mahoney says he may be nearing the burnout stage. Despite the endurance he's gained as a runner (having completed five marathons, he'll run in the New York City Marathon again this fall with his wife), he says the stress of the ER is tiring. Adding to the usual pressures of ER medicine is the new threat of violence against health care providers.

Security officers at St. Luke's have confiscated knives and guns from family members and patients, alike.

Health care reforms brewing in Washington are likely to change one aspect of life in the emergency room for the better, by reducing the walk-in cases many people bring to emergency rooms because they have no where else to go. Mahoney looks forward to that change. "In busy times, patients can wait two and a half to three hours to see a physician," he says. "Treating routine illnesses through the ER just bogs down the system and diverts attention from acute cases."

Yet even in this pre-reform world, Mahoney finds his work rewarding. "You develop a real camaraderie with your co-workers," he says. "We really pull together. And, working in the emergency room, I know that if we hadn't been there, some of those patients might not have survived."

—Allison Chisolm



Emergency room physician Mark Mahoney says he sees "everything" in the way of medical problems during a typical 12-hour shift in the emergency room of St. Luke's Hospital in New Bedford, Mass. Clockwise from left, on a recent summer afternoon in the ER a photographer caught him stitching up a wound, checking the X-rays of a patient before deciding on a course of treatment, doing a routine exam on a walk-in patient, and bandaging an injured foot.

GEORGE BATTEN HAS DEDICATED HIS LIFE TO HELPING OTHERS LIVE UNTIL THEY DIE

An 84-year-old New Jersey man, diagnosed with cancer, had about a month to live. A lifelong artist and photographer, he attended an exhibit of his work arranged in 10 days by staff members of West Essex Community Health Services/West Essex Hospice, a local health service agency. Forty people, a cable TV station and the Newark *Star-Ledger* came to his opening party to see the art and to honor their old friend.

"We believe it's important to do things for people while they live," says George Batten '67, executive director of West Essex Community Health Services Inc. in Verona, N.J. His staff's work on the art retrospective is typical of their efforts to help clients enjoy their last days.

Batten takes life seriously. He has spent nearly 15 years helping people live until they die through the West Essex Hospice program sponsored by West Essex Community Health Services. He directs a corps of 150 visiting nurses, home health aides and physical therapists who enable terminally ill clients to stay at home and still be safe.

Batten and Barbara Piwinski, home health aid training director at West Essex Community Health, present a certificate of training to Joyce Fugate.

"We're trying to make people as independent as possible so they don't have to move into an institution for their last days," says Batten. "Almost two generations of people have grown accustomed to dying in hospitals. We've gotten away from home care and we can't afford to continue that way."

Batten notes that 20 to 30 percent of all health care expenditures are spent in the last year of a person's life. Hospices offer a money-saving option by providing services outside institutions. The concept should appeal to the Clinton administration's health care reformers, he says. "So much of health care is still controlled by doctors and hospitals," Batten says. "There's not enough interest or money in preventive care—keeping people healthy and out of institutions."

Batten came to West Essex in 1974 with a master's degree from Cornell's School of Business and Public Administration. "I was anxious to put all my grand ideas to work," he says. A management engineering major at WPI, he decided he wanted to help people, though he didn't want to work in industry. He found a mentor in Robert Hall, former professor of management and director of continuing education at WPI. Hall helped him think through possible career choices and suggested health care administration.

After graduating from Cornell's program, Batten worked for two years as a planner for the Health Planning Council for Greater Boston, examining overlapping health services in the area. There he met Alice Dempsey, then executive director of the Boston Visiting Nurse Association. She helped him land a job as state associate director for the Home Health Agencies in New Hampshire and Vermont. It was while doing that job that West Essex Community Health Services recruited him nearly 20 years ago.

He began the hospice program at West Essex Community Health in 1979 and recently added a personal emergency response system to the other more traditional visiting nurse and hospice services. A pager worn as a necklace or belt buckle allows for two-way conversation in an emergency with an operator who can summon help. Caring for the caretakers is another concern of Batten's. With this new response system in place, they can leave their patients for short relief periods to run errands and do other things outside the home.

Batten is clearly in a growth industry. The fastest growing segment of the American population is women over 85, and the number of AIDS cases among younger people continues to rise. Both populations benefit from home care services, he says. In fact, the past two years have seen a 25 percent annual increase in home visits by West Essex staff members.

Serving about 600 patients monthly in mostly suburban communities surrounding Newark, Batten's staff made 6,300 patient visits in June alone, which translates into 75,000 visits per year. On any given day, West Essex staff cares for about 70 hospice clients.

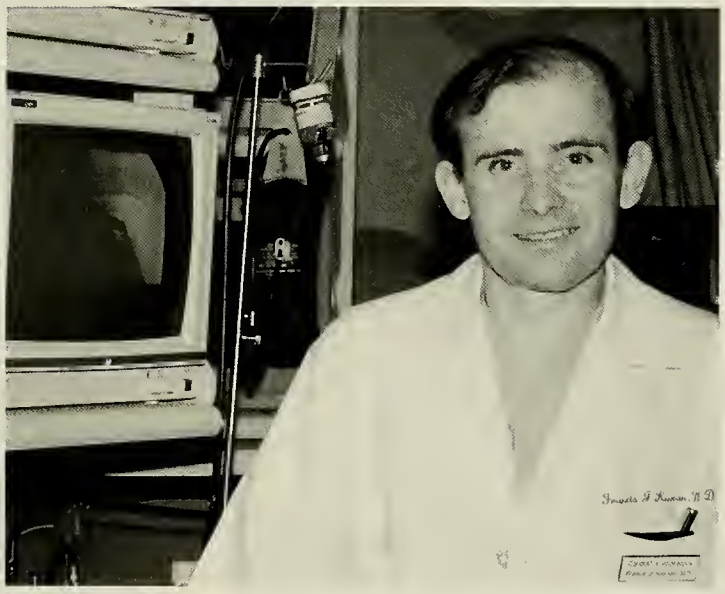
Managing workers who see death every day requires great sensitivity and support, says Batten. A nurse with a psychiatric specialty works both individually and with groups of staff members to discuss handling their own grief. "Most nurses have one patient die each day," Batten says. "You have to have empathy for the patient, but not sympathy. Sympathy means you take your work home with you. You have to be able to carry on your own life or you'll burn out."

Batten follows his own advice with an active home life. He and his wife, Kathleen, enjoy jogging and tennis, and they take 12-year-old daughter, Abigail, on family ski trips and white water canoeing outings. He says celebrating life helps remove the stigma of death. "I shuffle paper all day long," he says. "But I can go home at the end of the day knowing I'm helping people enjoy their last days."

—ALLISON CHISOLM

FRANCIS KIERNAN PROBES THE HEART FOR SIGNS OF DISEASE

As assistant director of the Cardiac Laboratory at Hartford Hospital in Hartford, Conn., and clinical professor at the University of Connecticut School of Medicine in nearby Farmington, Dr. Francis Kiernan '75 specializes in interventional cardiology, which uses invasive techniques to diagnose problems in the heart. These techniques include angiograms and angioplasties, he says. An angiogram is a diagnostic test in which a rapid sequence of X-ray images is taken of an artery or vein after a dye opaque to X-rays is injected into the blood vessel. By recording how the dye passes through the vessel, the test can determine its shape and locate places where it may have narrowed or become blocked. Narrowing can indicate the presence of blood clots or atherosclerotic plaque, Kiernan says.



RICHARD D. MOORE, JR.

Angiography can also be used to diagnose problems in the cavities and valves of the heart, and can provide information about the heart muscle itself, Kiernan says. "We can see if the muscles of the pump are weakening, since the catheterization procedure will measure the blood pressure and flow in all of the chambers of the heart."

When fatty deposits narrow one of the coronary arteries that feed blood to the heart muscle, it can be widened with angioplasty. The procedure involves inserting a balloon catheter into the vessel and inflating it. "The first angioplasty was done in 1977," Kiernan says, "but the procedure did not take off in the United States until around 1980."

The benefits of angioplasty are two-fold, he notes. First, the inflated balloon compresses plaque against the walls of the artery and creates a channel that restores more normal blood flow. The technique is often used to restore blood flow to the heart after a heart attack and in patients with angina, a condition marked by severe chest pain caused by insufficient oxygen reaching the heart muscle.

Second, the procedure, which requires only a two-day hospital stay, can help patients avoid the need for bypass surgery, which requires a week's hospital stay and at least six weeks of home recuperation. Kiernan says about 1,000 angioplasties are done each year at Hartford Hospital, a major teaching facility in central Connecticut with 900 beds and a large program in cardiac teaching and research.

Kiernan became interested in interventional cardiology as a resident at Hartford Hospital. In part, he says, he was attracted by the prospect of helping treat and diagnose a major killer of Americans. "Heart disease is a major source of mortality," he says. "We see it develop in people in their 40s—sometimes in their 30s. Factors such as diet, family history and smoking are among its leading causes." One of the fastest growing fields of medicine, it is also one marked by constant technological developments. "It's a very technical field, in terms of equipment and concepts. There are lots of gadgets," he notes with pleasure.

Kiernan dates his interest in medicine to his days as a life sciences major at WPI. "I had an inkling then that I might want to do this," he says, noting that the Institute gave him some of the skills he finds valuable in his work today. "WPI taught me the concept of working independently to think out problems. Each patient we get presents a new set of challenges. We use the knowledge we've gained, and the new techniques we have available, to make things go smoothly."

In addition to overseeing a broad program of diagnostic and therapeutic tests at the hospital, Kiernan conducts research with experimental devices. He says he got his first taste of medical research at WPI. For his Major Qualifying Project, he was part of a team that studied how the shape of red blood cells changes when they are affected by chemical stress, sickle cell anemia and enzyme deficiencies. The results of the project, which was conducted at Saint Vincent Hospital in Worcester, were published in the journal *Blood*.

Currently, Kiernan is studying an experimental catheter that will remove plaque from blocked arteries. Factors that increase the risk of plaque buildup include heredity, high blood pressure, high cholesterol, smoking and diabetes. "It's an experimental rotational atherectomy device being developed by one of the angioplasty manufacturers," he says. "We've been working with them on an early prototype to help refine the design."

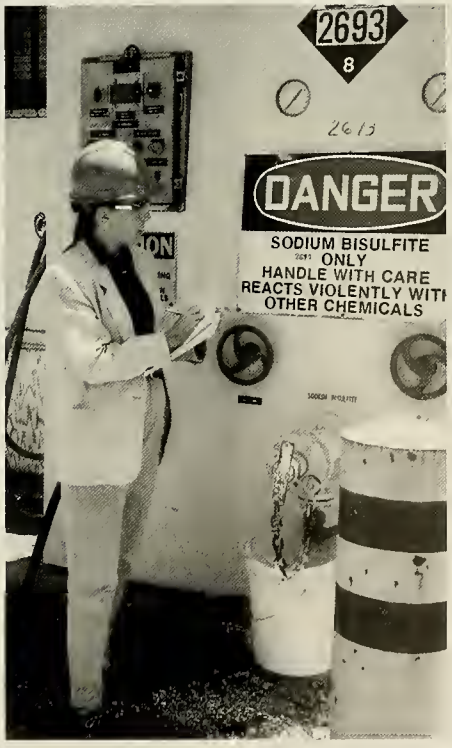
The unique device, which is just a few millimeters in diameter, consists of a stainless steel mesh coated with an abrasive. When attached to a catheter, it will be used to shave the plaque from the artery walls. The procedure should not damage a normal artery, Kiernan says. "It's now being tested in the lab, but not yet in patients. I hope to be able to use it on patients within a year or so."

—CAROL CAMPBELL

Carolyn Jones Protects Health of City and County Workers in San Francisco

I was always interested in health-related issues, even as a mechanical engineering major," says Carolyn Jones '79, an industrial hygienist for the Environmental Health and Safety Program of the Department of Public Works for the City and County of San Francisco. "In fact, my plan was to be a biomedical engineer."

But Jones had a change of heart after she attended a conference on women's health in the workplace while still an undergraduate. "That was where I discovered industrial hygiene as a career field," she says. The discipline seemed to offer an ideal blend of engineering and health, but none of the companies she interviewed with had jobs in the field.



The one exception was the Air Force, which offered her a post as bioenvironmental engineer, a job that included work in industrial hygiene, environmental engineering and emergency response. After seven years, she left active duty and entered the reserves so she could study for a master's degree in public health with a concentration in industrial hygiene at the University of California at Berkeley. She then worked for one year at a public utility before taking her present position in 1989.

Industrial hygienists, Jones says, "identify, assess and recommend controls on workplace hazards." While safety engineers deal with physical hazards that might cause serious injuries, industrial hygienists evaluate environmental hazards like toxic chemicals, radiation, noise and vibration. They may also evaluate ergonomic hazards that can cause conditions like carpal tunnel syndrome.

"Employee training is also a large part of our job," she notes. "We teach people how to recognize when they are working with a hazardous material like asbestos, how they can learn about such materials and their hazards, and how to protect themselves. We teach them to think about the substances they work with so if they develop medical problems or symptoms at work, they'll know what might be causing them."

When employees report such problems, Jones determines the chemicals contained in the products they use and looks at the known clinical effects of those chemicals. She may take air samples to measure the concentrations of the chemicals in workplace. If appropriate, she'll make recommendations to reduce worker exposure, perhaps by substituting a different product, improving ventilation, or giving workers heavy-duty gloves or respirators.

Regulations governing permissible workplace exposure to chemicals are promulgated at the federal and state levels, Jones says. "Exposure limits are set such that the vast majority of workers will be protected, but they don't guarantee that every worker will be protected. A person with a greater than average sensitivity to a particular substance might have problems at a level that is perfectly safe for everyone else."

Recently, the procedures the San Francisco DPW uses at two specific sites to minimize worker exposure to hazardous materials were evaluated by a team of WPI students completing an Interactive Qualifying Project at the San Francisco Project Center. The project was one of three sponsored by the department.

"I was happy to see that the students found our procedures to be good," says Jones, who was instrumental in arranging the department sponsorship. "It was nice to have somebody with an unbiased opinion come in and look. All three projects worked very well."

The field of industrial hygiene was first recognized as a profession in the 1930s, Jones says. It grew slowly until 1970, when Congress passed the Occupational Safety and Health Act. The need to comply with the myriad federal regulations that resulted from that act created a demand for industrial hygienists. Today there are about 10,000 people in the field in the U.S.

Many work for large companies, although there are also jobs in federal, state and local governments, consulting firms and academia. "Industrial hygienists come from all sorts of backgrounds, including environmental sciences, biology, chemistry and engineering," Jones says. "Chemical engineering is good preparation because it helps you evaluate chemical processes. Mechanical engineering is also good because a lot of the work industrial hygienists do is in industrial workplaces and mechanical engineers understand the processes used in these environments."

While concern within government and industry for worker safety and health has increased over the past two decades, Jones says public opinion has lagged behind. "Unfortunately, the public gets far more upset about environmental hazards than they do about workplace hazards. They're more apt to act if they think that a company is polluting a stream than if they think a company is harming its employees. I think people see what affects them, and environmental hazards affect them more directly."

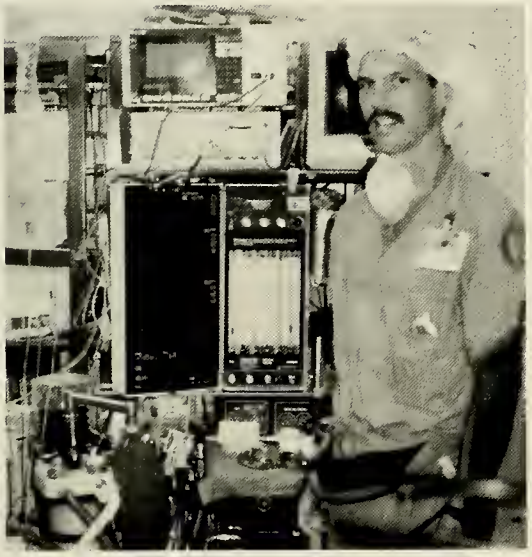
—Diane Benison

Split-Second Decisions Punctuate Long Days for Anesthesiologist William AuBuchon

Dr. William AuBuchon '82 has often demonstrated that he is not afraid to take on challenging opportunities. That is particularly true in his choice of career paths. As a second-year anesthesia resident in training at Vanderbilt University Hospital in Nashville, Tenn., he often makes the kind of split-second decisions that can only be evaluated in hindsight. He says he is accustomed to work that involves precise calculations, a steady hand, and clear, quick thinking.

As a resident, AuBuchon has also become accustomed to a grueling schedule, which includes 50- to 90-hour work weeks and being on call every fourth night. "I'm usually dressed and in the operating room by 6 a.m.," he says. "I may remain in the hospital until 8 p.m. Some days I'm on call for 25 hours. I generally have just one free weekend a month."

He is involved in two to four operations a day, each spanning from 30 minutes to four or more hours. While he generally does not see a patient again once a procedure is complete, he may spend several hours in preparation for the operation the evening before. "I have to do a history and physical exam for each patient, review the X-rays and lab work, review any prior diagnosis, and evaluate the patient's overall medical condition and other related problems."



The next morning AuBuchon helps prepare the patient for surgery in a holding room adjacent to the operating room. "For an uncomplicated case, we insert an intravenous line into an extremity vein; a complex case, such as a liver transplant, requires multiple lines that include a heart monitor inserted through a neck vein and floated into the heart chambers," he says. An arterial catheter, which measures blood pressure, is inserted directly into an artery in the leg or arm to assure continuous accurate readings. The catheter is connected to an electrical transducer that is, in turn, plugged into a display screen.

Throughout an operation, the anesthesiologist is constantly busy, AuBuchon says. Each operation is unique, he notes, so the anesthesiologist must prepare an individual anesthetic plan for each case—even if it involves a procedure he may have done many times before. The length of the case, the surgeon, and the patient's age, medical problems and tolerance for certain medications and techniques are all factors that must be considered individually.

Though he was an electrical engineering major at WPI, AuBuchon focused both of his qualifying projects on medicine. For his Interactive Qualifying Project, completed at Norton Co. in Worcester, he examined ways the company could save money by purchasing generic rather than name-brand drugs for its employees. He also studied several programs for Norton, including the feasibility of establishing a company drug store and a proposal to arrange a discount program for employees at a local pharmacy.

For his Major Qualifying Project, AuBuchon was part of a team that worked with biomedical engineers at Saint Vincent Hospital in Worcester to build a customized Holter Monitor, a portable device used in cardiology that records key parameters about a patient's heart over a 24-hour period. He says the emphasis of the WPI Plan on problem solving has proved valuable in his profession. "We had to take facts and circumstances, define the problem, and then try to master it. That's what I do in my work now."

After AuBuchon graduated from the Tufts University School of Medicine in 1986, he and his wife, Lesley, moved to Tennessee, where he completed an internship at the University of Tennessee Medical Center at Knoxville. In 1987 he entered the U.S. Navy as a general medical officer in fulfillment of his Naval scholarship obligation. He served until 1992.

As part of his naval training, he was stationed in Pensacola, Fla., where he attended the Naval Aerospace Medical Institute and studied aviation medicine. He also received basic cockpit flying instruction "to get a grasp of what pilots undergo, especially under stressful conditions." That training proved helpful when he was deployed to Saudia Arabia as a flight surgeon with a Marine Corps helicopter squadron for seven months beginning in August 1992.

AuBuchon says his military experience has proven helpful in his work as an anesthesiologist. "Administering anesthesia requires you to think on your feet," he says. "You are often involved in procedures that could mean life and death for the patients. It's not unlike flying an airplane. It requires you to make immediate, rapid responses, then make your evaluations based on what happens."

He says part of the challenge and excitement of the field is keeping up with the constantly changing technology available to anesthesiologists. He says that technology has changed dramatically since he was a medical student. "In 1985 most operating rooms were not yet using devices like the pulse oximeter, which indicates the fraction of oxygen saturated hemoglobin in the bloodstream, or the mass spectrometer, which measures the concentration of inhaled gases. These are now essential tools."

—Carol Campbell

LAUREN BAKER PAVES THE WAY FOR CLINICAL TRIALS OF NEW MEDICAL DEVICES

As preclinical program manger for new experimental medical devices at Boston Scientific Corp. in Watertown, Mass., Lauren Stratouly Baker '82 has carved out a unique niche for herself in the halls of medicine.

Baker, who has been with Boston Scientific for about two years, works with a special team developing information the Food and Drug Administration requires before it can approve clinical trials for new medical technology. "These devices include permanent body implants as well as devices that are in the body for only a short time, such as the balloon catheters used by cardiologists to do angioplasty," she says.

The documents Baker prepares describe in detail the results of mechanical tests and other procedures that demonstrate the integrity and performance of the new devices. Also included is a literature review that shows how the product is to be used and summarizes any clinical experience that may have been gained with the product in other countries.

Finally, the FDA submission includes a clinical investigation plan, which describes how the human clinical trials will be conducted. "These submissions are quite a chore to develop," Baker says. "Sometimes I think they're worse than writing my dissertation."

Baker is also responsible for supervising all clinical trials of Boston Scientific products conducted outside the U.S. "This facet of my job has enabled me to take several trips to Europe. This is particularly challenging, given the time changes and language barriers, but the trials provide our development team with vital information on product performance."

The third phase of Baker's job is new. She says she is developing a testing facility the company can use to evaluate the essential performance of its products. The facility will ultimately include laboratory models of a number of physiological systems—such as coronary arteries or gall bladder bile ducts—in which or upon which Boston Scientific products are designed to operate.

"This aspect of my job utilizes my engineering background the most and consequently offers me the most technical challenge," she says. "I also work with all the engineering and marketing groups within the company, as well as with many outside physicians."

Before joining Boston Scientific, Baker was an assistant professor in the Department of Surgery and co-director of the Division of Cardiothoracic Research at the University of Massachusetts Medical School in Worcester. Her job there was devoted to research on the mechanics of the heart. In that post she was involved with the design, manufacture and maintenance of instrumentation used to monitor heart functions. The equipment was employed in research on the treatment of cardiovascular disease.

The instrumentation she helped develop included a device that monitors tissue pH and potassium levels during cardiopulmonary bypass surgery, a balloon catheter that can be inserted into the heart through the pulmonary artery and inflated to assist a failing right ventricle, a catheter that uses impedance plethysmography to determine ventricular volume, and a noninvasive cardiac output monitor.

She was also involved in a number of research projects at the medical center. With a grant from the National Institutes of Health, she helped investigate the effects on the heart of tumor necrosis factor, a protein found in the body that destroys cells that divide abnormally. Another project tested the use of warm cardioplegia (a technique in which the heart is temporarily stopped) during coronary bypass surgery.

As a faculty member at UMass, she taught the techniques of signal processing and data acquisition and analysis to research fellows, medical students and graduate students in her division, and developed and managed a database system for tracking all cardiovascular surgery patients. She managed and hired division personnel, designed and managed the yearly budget of the division, and coordinated the preparation of grant proposals and manuscripts.

Until recently, Baker also served as an adjunct assistant professor of mechanical engineering at the Institute, teaching courses in fluid mechanics, stress analysis, engineering statics and biomedical engineering, and advising graduate and undergraduate research projects.

Baker earned her B.S. in chemical engineering at WPI and went on to complete a master's and a doctorate in mechanical engineering at the Institute. In 1985, she won WPI's Outstanding Thesis of the Year award for her master's thesis, "Noninvasive Detection of Arterial Occlusive Disease: A Theoretical and Model Study." For her Ph.D. dissertation, she developed an analytical and experimental model to study the propagation of a pulse through an artery in healthy and diseased individuals.

Although Baker says her job is demanding, she and her husband, David Baker '81, still find time for recreation. They enjoy sculling and are officers of Friends of WPI Rowing, an organization established through an endowment provided by the late Professor Richard

Thomas Gudewicz' Specialty is How the Human Body Works Deep Beneath the Sea

Fifteen years after he graduated from the Institute, Lt. Cmdr. Thomas M. Gudewicz '78 remains enthusiastic about WPI's project-based education. Now in the third year of a four-year residency at the Naval Medical Center at San Diego, he is one of many alumni who leveraged their technical education into a career in medicine.

Dr. Gudewicz had been accepted to WPI by the time he graduated from high school, but he enrolled as a mechanical engineering major at the University of Connecticut because, as a state school, it was significantly cheaper. After one year in UConn's traditional engineering program, Gudewicz, unhappy, dropped out and took a job as an apprentice machinist at Pratt and Whitney to earn some of the money he needed to attend WPI. He hadn't abandoned the notion of going to an engineering school, he just wanted a different kind of engineering school.

"I wanted to get my fingers into the pie as soon as possible," he says. "I'm a poor book learner, but give me a practical problem and I'll solve it and learn the concepts a whole lot better. I loved the WPI Plan. I could not have survived college if it were not for the Plan. I'm sort of nontraditional and WPI is a nontraditional school."

By the time Gudewicz enrolled at WPI, his interest in mechanical engineering had waned (his experience at Pratt & Whitney helped him decide the field was not for him). He ultimately decided to major in the life sciences with the idea that he'd figure out a way to meld that field with his already well-developed love of the undersea world.

Stan Waterman, the undersea filmmaker, was a friend of one of Gudewicz' high school teachers at Wilbraham and Monson Academy in Wilbraham, Mass. Periodically, Waterman stopped by the school to show his films. Those films were the catalyst that prompted Gudewicz to get certified as a sport scuba diver; they also started him on a path that eventually led to medicine and the Navy.

At WPI, his love for diving became a passion. Three or four times a semester, Gudewicz made the two-hour trek to Massachusetts' North Shore with Ronald Fish '78 and William Dino '75, both certified scuba divers. They'd leave campus at 2 a.m., enter the water while it was still dark, and return to Worcester in time for 8 a.m. classes.

His interest in diving helped shape his studies. "I took engineering courses," he says. "I took chemistry, biology, physiology, etc. I did an IQP in marine biology and an MQP in biochemistry. I was sort of headed toward the water even then." He also found time for an independent study on nitrogen narcosis, a danger for scuba divers.

As graduation approached, he considered his options. "I really don't want to go to graduate school," he remembers thinking. "I really don't want to go to medical school right now. What I really want to do is get a job, make some money, and live a life, not as a poor student, but as a normal human being."

So after graduation he went to the University of Texas Medical Branch in Galveston, Texas, with the intention of working with Brian Hills, a chemical engineer who had done thermodynamic studies of decompression sickness. But when Gudewicz arrived, he discovered that Hills' grant hadn't been approved. There was no job.

He used his chemistry background to get a job as a technician in the biochemistry department at Baylor College of Medicine. "It was there that I was introduced to a working research laboratory, to laboratory management, to experimental design, to instrumentation, to writing papers, to getting grants, and so on," he says.

He says his life sciences education had prepared him well for work in biochemistry. "It doesn't really matter whether you're doing biology, molecular biology or biochemistry. They all use the same techniques nowadays—restriction enzymes, DNA probes, etc. It's a molecular biology approach to research. People in all of the life sciences tend to understand each other."

After a few years, he decided it was time to get a "real career." He was accepted to the University of Texas Medical Branch in

Galveston, financing his medical education through the Armed Forces Health Profession Scholarship Program (AFHPSP). Under AFHPSP, the Navy paid his tuition and fees, bought his textbooks, and gave him a small stipend; in exchange, he agreed to give back one year of military service for each year of education he received. The Navy program was appealing, Gudewicz says, because it held the prospect of work in underwater research. "I figured, the Navy has the water—they're the guys to be with."

After he received his medical degree in 1986, he did an internship in internal medicine at the Naval Hospital in San Diego. Before going on to a residency, he chose a four-year operational tour in undersea medicine as part of his obligation to the Navy. His tour included a six-month program at the Navy's submarine training center in Groton, Conn., nine weeks of diving training at the Navy Diving and Salvage Training Command (NDSTC) in Panama City, Fla., and four months of specialized training in saturation diving at the Naval School of Deep Diving Systems (NSDDS) in Charleston, S.C.

"We learned a little bit about submarines and submarine medicine," he says. "Since we have nuclear submarines, we also learned something about radiation health. And, since we're going to be dealing with divers, they sent us down to a course in diving medicine. At NDSTC we trained in all Navy diving techniques, including using heliox (helium-oxygen) for deep-sea diving. We are now certified Navy divers. We can go anywhere in the world where the Navy dives, be issued equipment, and dive with Navy divers."

Gudewicz, only the second physician to complete the course at NSDDS in Charleston, says the training was designed to prepare him for his assignment at the Commander Submarine Development Group I in San Diego, created by the Navy after the loss of the nuclear sub *Thresher* in April 1963. "It consolidated Navy programs involving submarines, deep-submergence vehicles and saturation diving techniques into one command responsible for overseeing the development and implementation of complex systems used for various operational reasons," Gudewicz says.

Among the technologies developed by the San Diego group are deep-submergence vehicles (DSVs), which can carry out scientific and salvage operations at depths down to 15,000 feet; deep-submergence rescue vehicles (DSRVs), used in submarine rescue operations; salvage and rescue platforms for use with DSRVs; and equipment and techniques for saturation diving. "The whole problem with saturation diving is that when you do a dive you breathe an atmosphere at the pressure of the water around you, so your tissues absorb the gases at that pressure," he says.

"When you come to the surface, the ambient pressure is low, but the pressure of the gases within your tissues is high. So if you ascend too rapidly, the gasses bubble out—it's like opening a bottle of soda pop." Gas bubbles can be fatal, he adds.

If a diver works under pressure for only a short time, decompression on the surface poses little danger. But long dives, for example salvage operations that involve numerous long dives over several days, require saturation diving. Such operations are usually carried out by several teams of divers who work in shifts. The divers are pressurized at the surface to the depth at which they'll be working. They remain under that pressure until the work is complete, descending to the work site in personal transfer capsules (PTCs) and returning to the ship to rest in between shifts in a deck decompression chamber.

"When you come to the surface, the ambient pressure is low, but the pressure of the gasses in your tissues is high. So if you ascend too rapidly, the gasses bubble out—it's like opening a bottle of soda pop."

"That is much more cost-effective—and safer," he says. "When the job is done, you decompress the divers at a very, very slow rate. Of course the deeper you go the more problems there are, including physiological problems. That's where I came in."

Recently, Gudewicz left the undersea world to pursue additional training in pathology and laboratory medicine. His work now focuses on anatomical and clinical pathology. He says one of the reasons he chose pathology is because it "gives you a broad view of medicine." He says he also enjoys the analytical work.

"Anatomical pathology has to do with the anatomical manifestations of disease," he says. "Anytime tissue is removed from the body by a surgeon, it is sent to us for analysis and diagnosis. We are physician consultants, with surgical pathology constituting the biggest portion of this field."

Gudewicz also works in cytology, which is the diagnosis of disease based on the microscopic examination of cells. "You can use a small needle to aspirate a few cells, and then look at those cells to determine important characteristics, such as whether they are malignant or benign. You direct therapy from there. You can get a diagnosis quickly, but you have to train your eye to distinguish healthy from unhealthy cells."

Gudewicz also supervises the microbiology lab, the blood bank and blood component therapy and does analysis of blood and other body fluids, he says. "Years ago, the clinical pathologist had a lot more hands-on work to do in these analyses, but now most of it is automated. Today, we have to be familiar with the problems associated with the answers that the machines generate and how those problems relate to the clinician's decision-making process."

When he finishes his residency, Gudewicz will still owe the Navy two years. After that, should he choose to continue to work for the service, he says he might like to serve at a naval diving training unit or at the Navy Medical Research Institute in Bethesda, Md. But wherever he goes, he'd like to continue to do research into the way human physiology works under the sea.

—DIANE BENISON

After a Long Career in Clinical and Biomedical Engineering in Arizona, Emanuel Furst Tries Consulting

After 21 years as director of biomedical engineering at the University Medical Center in Tucson, Ariz., Emanuel F. Furst, who received his Ph.D from WPI in 1969, says he is once again asking himself the age-old question, "What do I want to be when I grow up?" Since his position was eliminated earlier this year—the result of the merger of two departments at the hospital—he has been preparing for a new career as a consultant.

Furst joined the faculty of the University Hospital (now the University Medical Center) in 1972. He was also named an assistant professor of electrical engineering at the University of Arizona. "I was hired to bring an engineering perspective to the hospital and to develop collaborative research and teaching programs between faculty in the colleges of Engineering and Medicine," he says. "I provided consulting in areas such as electrical safety and the use of medical equipment."

He taught electrical engineering part time for several years. His other responsibilities included advising the hospital on the types of medical equipment it needed, making sure the hospital continued to meet the requirements for accreditation, and investigating unusual incidents involving medical equipment to assure that similar problems would not occur again.

He was also instrumental in developing the Shared Service Maintenance Program in collaboration with the University of Arizona's College of Engineering. The program provided maintenance services and engineering consulting to rural hospitals in Arizona, freeing the hospitals from reliance on manufacturers to repair and maintain equipment.

This is especially important in rural areas where hospitals are far removed from manufacturers' service representatives, resulting in substantial delays and increasing the cost of service visits, Furst says. The program was started with a grant from the W.K. Kellogg Foundation. The grant also enabled Furst to launch an academic program in clinical engineering—a field that merges medicine and engineering—at the university.

Furst says it was his expertise in equipment management and regulatory matters that led him to consider consulting. He says his interest in regulatory issues includes safety, plant and equipment management, and requirements for obtaining accreditation. He serves on an advisory committee of the Joint Commission on Accreditation of Health Care Organizations, a voluntary agency. Accreditation qualifies hospitals to bill through the Medicaid system.

At the University Medical Center, Furst says he also developed a great deal of expertise on the Safe Medical Devices Act of 1990, an effort of Congress and the Food and Drug Administration to promote the safety of medical devices. Since 1986, he has served on an FDA panel that reviews applications from manufacturers for approval for new high-risk medical devices.

He says these experiences, in addition to his work at the University Medical Center, have convinced him of the value of having an engineer involved in the evaluation and selection of new technology for hospitals. "Many hospitals don't take full advantage of what engineers can do and the expertise they can bring to hospital management in purchasing, operating budgets, and the design and maintenance of facilities," he says.

Furst received the first Ph.D. in biomedical engineering awarded by WPI. Before coming to the Institute, he received his bachelor's degree at Clarkson University and his master's at Columbia University. He then worked for three years as an assistant professor at California State Polytechnic University. While there, he received a National Science Foundation grant to attend a summer graduate program.

For two summers, he came to WPI to take graduate courses. Then, after another year of teaching, he enrolled full time in the Institute's new graduate program in biomedical engineering. He did his dissertation research in neurophysiology at the Worcester Foundation for Experimental Biology. The work involved recording the signals from individual neurons in the cerebellum that respond to the body's position in space.

After receiving his Ph.D., he worked for three years as a development engineer at Hewlett-Packard Co. before joining the University of Arizona. In the late 1980s, Furst was honored for his career achievements in biomedical and clinical engineering when he received the Clinical Engineering Achievement Award from the Association for the Advancement of Medical Instrumentation.

—Carol Campbell

Chandler Jones is Home as Host of Venerable Old Cobb's Tavern

Nothing makes WPI Trustee Emeritus Chandler Jones '26 happier than welcoming a busload of school children to his home, Cobb's Tavern, a National Register of Historic Places treasure built in Sharon, Mass., about 1740. "I love having visitors come by," he says. "If I've got something interesting to show, I like to share it. I don't like to hide it away. The tavern gives kids a chance to see how people lived in the old days."

With help from local history writer Claire Forman, Jones recounts his tavern tales as they guide groups around the 12-room, black-shuttered colonial. Their presentations make the tavern come alive for guests of every age. Listening to Jones, it's easy to imagine 19th century innkeeper Jonathan Cobb pouring spirits in the taproom refreshing weary wayfarers during stagecoach layovers. A low bench in front of the 15-foot pine bar allowed male travelers to sit down before the fireplace for warmth.

The twin doors that open into the taproom from the outside, Jones explains, were deliberately made wide enough "so a couple of jolly fellows could go out arm in arm, side by side."

Female travelers of the day were not allowed to drink in the taproom; women were customarily relegated to an upstairs parlor reached via a winding, pulpit-style staircase. Legend has it, however, that Deborah Sampson, a Sharon Revolutionary War veteran, met with Paul Revere in the taproom to talk about her getting a pension for her military service.

The tavern stood between Boston and Taunton on the Old Bay Road, a link between Massachusetts Bay and Narragansett Bay, Jones says. It was a busy place with a lot of traffic on Bay Road going to Taunton and on to New York. It was also an ideal stopping point for coaches carrying the mail; in fact, Jonathan Cobb served as Sharon's postmaster and the taproom doubled as a post office (the post office sign now hangs over the fireplace).

In those days, Cobb's offered overnight accommodations with rooms in the main tavern and an annex. It was the biggest inn in the East, and for a number of years a 125-member traveling circus troupe stopped there every summer and performed on the grounds. The inn was large enough to put up the entire troupe. An 1846 poster in the taproom commemorates one of the group's many visits.

On their annual "Wheel Around the Hub," members of the famous Boston Bicycle Club made Cobb's Tavern their country headquarters, all enjoying Mrs. Cobb's dinners. Two years ago, the present-day Wheelman's Club recreated a portion of the first organized bicycle tour ever held in the U.S. on Sept. 11, 1879, and made the traditional stop at Cobb's.

According to Jones, the original house was built in the mid-18th century; a two-chimney brick end-addition was added about 60 years later. A large upstairs room with a unique barrel-vaulted ceiling served successively as a Masonic lodge meeting room, a ballroom and two bedchambers. In 1895, after more than 150 years of service, the tavern closed to the public when Jonathan's son, Warren, died.

In 1935, upon the death of Warren's daughter, Gertrude Cobb, the tavern left the family for the first time in 144 years. Fortunately, one of the subsequent owners appreciated historical homes. Frederick S. Tobey wrote *The Tavern at Cobb's Corner,* which is on file in the Library of Congress along with nine photographs.

Chandler Jones and his wife, Dorothy (now deceased), purchased Cobb's Tavern in 1959. "We loved the place right away," he says. "But we had somewhat of a dilemma because I was about to retire and we had to reduce our real estate holdings. Through my family I had inherited the Cape Cod birthplace of Katherine Lee Bates, who wrote *America the Beautiful,* and my wife had acquired her great grandmother's old homestead in South Berwick, Maine. In the end, the tavern won out."

Continuing the restoration of the tavern, which was begun by Tobey, became a labor of love for Jones. Guided by extensive research and reading, he was careful to make sure all work done on the sturdy structure conformed to the original construction. When part of the roof was replaced, he even saved the original hand-wrought iron nails, in case they would ever be needed to restore the inn's finish.

More than 30 years after the purchase, Jones is still enjoying life in his tavern-home, especially reading the thank-you letters he often gets from grade-schoolers after his guided tours. He still chuckles over the note he received a couple of years ago from a fifth-grade boy who wrote, "You are a real kind person and you are in really good condition for your age. Thank you for everything."

Opposite page, Chandler Jones tells visiting schoolchildren about the history of Cobb's Tavern. The 18th century inn, below, left, was once a stop on the "Wheel Around the Hub," an annual tour by the Boston Bicycle Club, top. Bottom, right, Jones shows off one of the unwieldy bicycles ridden by club members.

At 90, Chandler Jones can look back over nearly seven decades of achievement, most of it far removed from tavern-keeping. After graduating from WPI as an electrical engineer, he joined the New England Power Construction Co. of Worcester (now the New England Electric System), where he concentrated on engineering, purchasing, construction, safety, labor and operations. He retired as vice president of the New England Electric System in 1968.

During World War II, Jones was on loan to the U.S. government as a $1-a-year consultant with the Office of War Utilities, War Production Board. He was also a consultant to the Civilian Production Administration, the National Security Resources Board, the Mutual Security Agency and the Economic Cooperation Administration.

During the Korean conflict, he was on loan as a consultant to the Secretary of the Interior to help organize the Defense Electric Power Administration and, later, to the Atomic Energy Commission's Advisory Committee on Reactor Safeguards.

Jones was a professional engineer in Massachusetts, Vermont and Rhode Island and has been active in numerous local, state and national organizations. After he retired, he helped organize the Sharon Historical Commission and a historic district in the town.

A former member of the President's Advisory Council, Jones is also a past chairman of the Development Committee of the WPI Board of Trustees and a past president of the Boston and Providence chapters of the Alumni Association. In 1970 he received WPI's Herbert F. Taylor Alumni Award for Distinguished Service.

For now, Jones is content to preside over the venerable old tavern he calls home and to help give the youth of today a look at how their ancestors lived and enjoyed life. In the conclusion of his book on Cobb's Tavern, Frederick Tobey wrote, "whether or not the Tavern at Cobb's Corner will have any future history worth recording remains to be seen." Thanks to Jones and his dedication to keeping a bit of the past alive for future generations, the inn continues to make history quite worthy of note.

—RUTH TRASK

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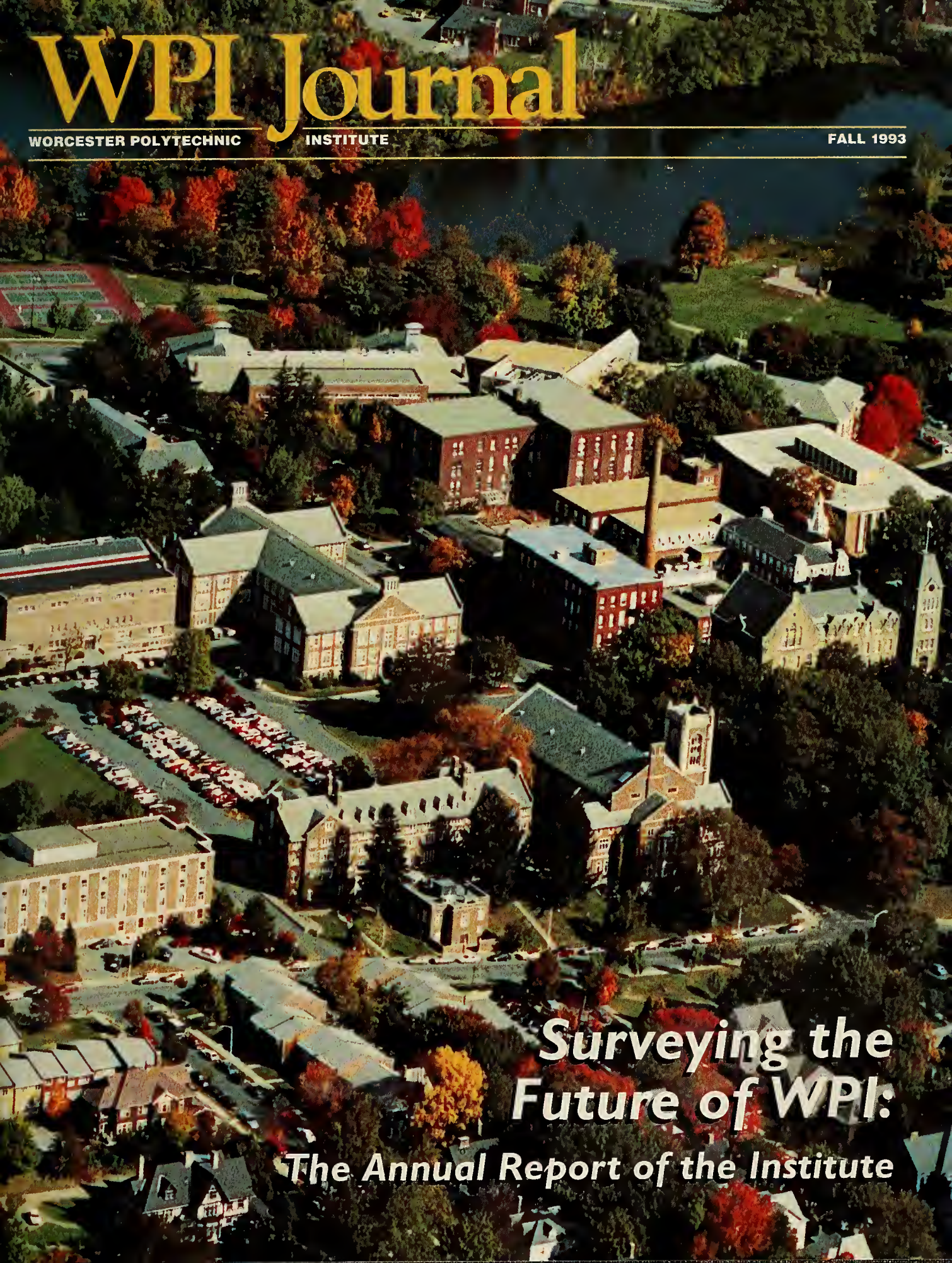
WPI Journal

WORCESTER POLYTECHNIC INSTITUTE

FALL 1993



Surveying the Future of WPI:

The Annual Report of the Institute

Group #3

WPI Journal

VOLUME XCVI NO. 4 FALL 1993

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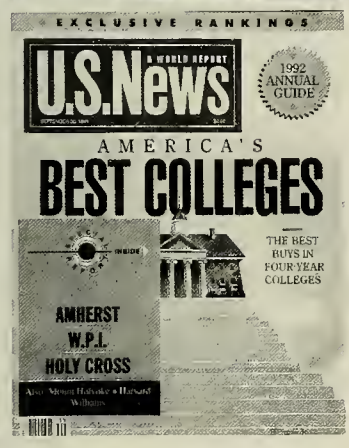

13

The Cover: The WPI campus is framed by fall splendor. Efforts now under way are aimed at determining what the campus—and the social and intellectual life that thrives within its bounds—should be like in the decades to come. Photo by Northeast Airfoto Service. **Opposite:** At the conclusion of a long and productive year of study, planning and open debate, the Blue Ribbon Task Force held an all-day forum in Alden Memorial to share its findings with members of the WPI community and to actively solicit their help in shaping the group's final recommendations to the Board of Trustees. Photo by Neil Norum. Story on page 3.

EDITOR'S NOTE: Each summer the Institute pauses a moment to reflect on where it's been and where it's going. As one fiscal year ends and a new one begins, it seems a natural time to look back at the accomplishments of the previous 12 months and to peer ahead at the challenges and opportunities that lie just over the horizon. The result of this reflection is the annual report. To place this year's report into the hands of as large a readership as possible, we've chosen to include it in the Fall issue of the *WPI Journal.*

As you will read in the pages that follow, this seems an especially fitting decision. In Fiscal Year 1993, the college completed a major period of self-evaluation and began the weighty task of determining how it will mold itself into the type of institution best able to thrive and grow in the decades ahead. To be successful in this process, the Institute will need the participation and enthusiasm of all members of the WPI community. It will also need to keep that community informed about how things are going here on Boynton Hill. Consider this report an integral part of that communications effort.

We hope you enjoy this special issue of the *Journal;* as always, we welcome your thoughts and opinions on what you find between the covers of this magazine.

— MICHAEL DORSEY

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Introduction

What's Next for WPI?

THIS ANNUAL REPORT, the eighth in the series spanning my presidency, focuses on the work of WPI's Blue Ribbon Task Force (BRTF). The BRTF, with its membership drawn from faculty, staff, students and trustees, was charged in 1992 with developing a comprehensive plan that will take the Institute through the 1990s and beyond. The plan was to be consistent with the goals of our strategic plan and was to give particular attention to the challenging financial environment in which we must operate.

I proposed this topic in last year's annual report because of its importance to WPI's future—and our future is what this essay series has been about. The series began seven years ago when I set forth an agenda for achieving strategic excellence at WPI. In each successive year, I have commented on some aspect of our progress on that agenda.

Along the way, I've reviewed the five-year plans of our academic departments, the progress made on those plans, the Institute's strategic planning process, the strategic plan that resulted from that process, and our encouraging progress in implementing the strategic plan despite the growing challenges we face. The series culminated last year with a report on how our own perspectives on this progress were validated by our decennial regional accreditation.

The Blue Ribbon Task Force ushered in a new era of community involvement in the planning of WPI's future and, perhaps more important, in the implementation of those plans. That spirit of participation, particularly as it affects how the Institute will act on the task force's recommendations, is reflected in this year's report.

The work of the BRTF was a major accomplishment. But as the members of the task force are the first to proclaim, that is not because they satisfied completely their charge to develop a comprehensive plan for the Institute. Rather, it is because this group of faculty and staff members, students and trustees

— first, confirmed that we face vexing, largely externally imposed financial problems,
— then, developed a framework for attacking those problems in the contexts of quality of life, academic experience and financial equilibrium,
— and finally, established a collegial, participatory process that encouraged all members of the campus community to take part. (That process—and the goodwill it engendered—may be the greatest hallmarks of the BRTF.)

These accomplishments are the prelude to a very challenging task. Now we must organize follow-on cooperative activities that will produce specific plans to implement the BRTF's recommendations for improving the quality of life and the academic experience at WPI while achieving the financial equilibrium necessary for our future well-being.

—JON C. STRAUSS

NORTHEAST AIRFOTO SERVICE

A Rough Draft of the Future

Building on the Work of the Blue Ribbon Task Force

By Jon C. Strauss
President

On Feb. 28, 1992, I charged the Blue Ribbon Task Force (BRTF) with evaluating both the challenges we face as an institution of higher education and the opportunities we might be ready to seize, given our unique academic program and our considerable human resources. Then, having laid this foundation, the task force was to propose an overarching plan to guide WPI along the road from what we are today to what we must become if we are to excel in the world of the next few decades.

Over the following 15 months, the task force undertook this prodigious assignment. After first defining their mission and their method of attack, they established subcommittees to study the various financial issues that impinge on the Institute's future and completed an extensive benchmarking study that measured our progress toward the six goals of our strategic plan against what our competitors have accomplished in similar areas.

In February 1993, the task force gave the WPI community a progress report in the form of two open meetings on campus and a presentation to the Board of Trustees. In April, task force members held numerous small-group meetings with the various constituents that collectively make up WPI. In May, the community had another chance to contribute to the planning process as the BRTF held an all-day campus meeting to present its findings and solicit input from the nearly 300 faculty, staff and students who attended.

The task force spelled out its recommendations on WPI's future in *Positioning WPI for the 21st Century,* its final report, presented to the annual meeting of the Board of Trustees on May 21, 1993. At right, we've reprinted the report's executive summary. In the following pages, I quote from many of the task force's specific recommendations. As I go along, I explain the steps being taken to evaluate and implement those recommendations.

In the conclusion to its final report, the BRTF urged that the next phases in WPI's evolution—the activities that will translate the task force's recommendations into a plan of action—"be organized and assigned by the administration to appropriate groups, keeping in mind the necessity to maintain community involvement and collegiality in the process."

The specific implementation processes I describe below are consistent with that request. They are presented along with the task force recommendations themselves in the categories of Quality of Life, Academic Experience and Financial Equilibrium.

Executive Summary of the BRTF Report

The world of the 21st century will be technologically sophisticated, rapidly changing and complex in its societal and ethical issues. To respond to emerging technologies and to national and international trends and needs, WPI should be a technologically based comprehensive university. Achieving this goal will require the WPI of the next century to build on three interrelated elements: quality of life, academic program and financial stability.

Quality is what we sell. In the coming decades, we must consistently strive to make a WPI education the best there is in an ever more competitive world. However, quality of programs is not enough. The social environment and the quality of the workplace must be improved for the entire WPI community in order to foster an atmosphere that allows the Institute to be a creative and exciting place in which to work and learn. The BRTF recommends that a campus center be built, that investments be made in staff educational programs, and that we develop a mechanism to foster communitywide communications. In general, we should invest in our most precious resource—the people who make up our faculty, administration and staff.

WPI's educational program (the Plan) is still relevant and appropriate to the needs of the 21st century. However, it appears unlikely that WPI can hope for much expansion from its current engineering and science base. A broadening of its programs in emerging interface technologies and the development of new, technically based initiatives are necessary. The BRTF recommends that WPI broaden along technological themes. The departments of Social Science and Policy Studies, Humanities, and Management must play a more vital role in developing interface technologies.

The BRTF further recommends that we expand our globalization efforts at both the graduate and undergraduate levels. As part of the overall educational program, we recommend that students be given a menu of possible ways ("time-tuition" programs) to finance their education. Finally, WPI needs to expand its continuing education activities to include interface technology areas of industrial interests, and to evaluate a part-time undergraduate program option.

WPI in the 21st century must be financially stable. All institutions of higher education face and will continue to face ever-increasing pressures to deliver high-quality education at a substantially reduced cost to both the institution and the consumer. The BRTF recommends that all programs be critically reviewed for quality and cost containment; that all new initiatives—both academic and administrative—be delivered at a low cost; that a severance plan be considered; and that the Institute invest in marketing our programs and our graduates, utilizing the alumni base where appropriate. The BRTF reaffirms the deferred maintenance program and recommends that any funding for major construction not involve the operating budget. Furthermore, the BRTF recommends that a marketing firm be retained to determine the appropriate emerging technologies to expand WPI's student and industrial populations, and to assess the marketability of time-tuition program options.

In conclusion, WPI must invest in all its people: students, faculty, staff and administration. Quality in all we do is essential to our continuing success. WPI must take advantage of its strengths in technology and broaden along technical lines; be sensitive to the needs of its customers, both financially and educationally; be flexible programmatically to meet their needs; and produce a higher quality program at a lower consumer and institutional cost.

The BRTF recommended:

- *That all sectors of the Institute adopt proactive communication mechanisms, including all-campus forums.*
- *That all sectors of the Institute—administration, faculty, students and staff—recognize the importance of such concepts as shared governance and community consensus.*

Quality of Life

Consistent with these recommendations—and the corresponding practices established by the BRTF itself—the Community Council will serve as the steering committee for the collegial implementation of the BRTF recommendations, much as it did this past year for the recommendations of the Commission on Residential and Social Life. The council, a representative body of faculty, staff and students, will schedule periodic open campus meetings to review the progress of the various groups assigned responsibility for specific recommendations and tasks.

- *That the Institute address the recognized urgent need for a campus center. We recognize that learning does not occur only in the classroom and that the needs of our students (as recommended by the Commission on Residential and Social Life) be seriously considered. Investments will be needed to attain these objectives.*

No one questions the priority of the proposed campus center project. The Physical Facilities Committee of the Board of Trustees is reviewing conceptual designs for two of the campus center concepts developed by Earl Flansburgh & Associates. These are a freestanding structure and a gateway/connector that might link to Daniels and/or Sanford Riley halls.

Further, the trustee Development Committee has begun to identify potential sources for the necessary funding. WPI's Office of Student Affairs, the undergraduate Student Government Association and the Graduate Student Organization will coordinate faculty, staff and student involvement in this work.

- *That the parking needs of our campus be addressed in a systematic and timely manner.*

WPI's Parking Committee will be reinstituted as soon as possible with a charge to organize a campuswide review of all options. It will be asked to develop, in cooperation with the trustees' Physical Facilities Committee, specific, financially feasible parking plans.

- *That the Institute invest in education and training of the work force.*

This recommendation reminds us again of the apparent dichotomy of an institution devoted to the education of others, and yet seeming to ignore the educational needs of its own work force. While progress has been made to liberalize the tuition remission benefit for our staff, and though extensive training in total quality management has been under way in the Office of Business Affairs, more needs to be done.

The Human Resources Office has been directed to review training needs in general and to begin immediately a new staff orientation program. The Office of Academic Affairs continues to improve the new faculty and administrative staff orientation program and is working with Business Affairs and Human Resources to organize a training program for new department heads.

- *That efforts be directed at integrating the students and resources of the graduate program into the mainstream of the WPI community.*

Mike Shipulski, president of the Graduate Student Organization, has articulated strongly the needs and attitudes of the Institute's graduate students. Dean of Students Janet Begin Richardson and the new dean of graduate studies and research will be working with the GSO to address this issue.

- *That the emphasis on globalization and respect for diversity that we have already launched be continued and increased.*

Globalization is seen by virtually everyone as a strategic priority for WPI. The Office of Academic Affairs is seeking to expand our global projects program and may market to students at other institutions the opportunity to do project work abroad next year. Good progress has been made on student and staff diversity, and a new Pluralism Action Plan, to be implemented in the 1993-94 academic year, will help increase respect and appreciation for difference throughout the WPI community.

JANET WOODCOCK

"Quality is what we sell. In the coming decades, we must consistently strive to make a WPI education the best there is in an ever more competitive world. However, quality of programs is not enough. The social environment and the quality of the workplace must be improved for the entire WPI community."

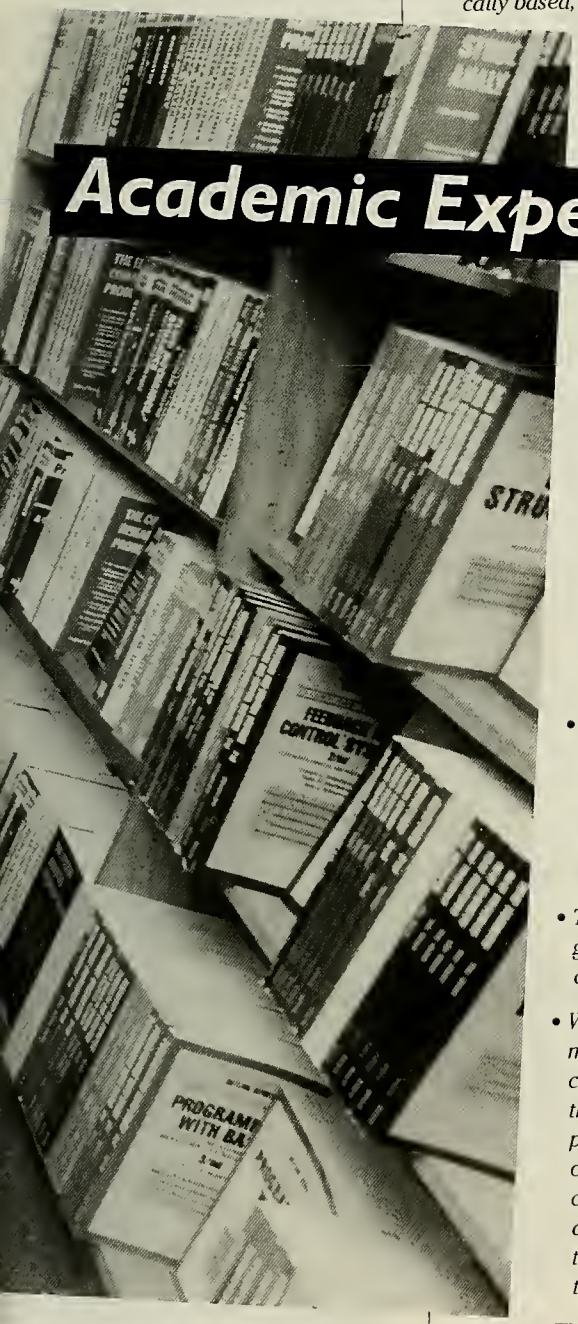
A member of the dance troupe Message From Our Ancestors performs at WPI's first African Marketplace in the spring of 1993. To improve the quality of life for all members of the WPI community, the Blue Ribbon Task Force recommended expanding WPI's globalization and diversity efforts. Other recommendations included building a campus center, improving communications on campus, investing in the education of WPI employees, and finding solutions to the Institute's parking problems.

JANET WOODCOCK

"WPI's educational program is still relevant and appropriate to the needs of the 21st century. However, it appears unlikely that WPI can hope for much expansion from its current engineering and science base. A broadening of its programs in emerging interface technologies and the development of new, technically based initiatives are necessary."

At the start of the school year last fall, a student searches the bookstore for texts he'll need for his courses. With regard to the Institute's academic program, the Blue Ribbon Task Force recommended that WPI become a technologically based, comprehensive university, broadening its scope to include a greater role for disciplines like the humanities and the social sciences, and developing the flexibility to respond to society's needs by offering unique, interdisciplinary majors.

Academic Experience



The BRTF recommendations in this area can be grouped as follows:

- *That the WPI of the 21st century be a technologically based, comprehensive university.*
- *That the concepts of the Plan be broadened to extend to humanists who need to function in a technological world.*
- *That WPI's 'broadening' include a more vital role for the Humanities and Social Science and Policy Studies departments in contributing to these emerging interface technologies in generating revenue by offering unique technology-based majors in these disciplines (technical journalism, technical theater, environmental law, etc.). We also recommend a more vital role for such departments as Management.*
- *That WPI develop an organizational structure and mindset that can respond to society's needs. We must have a flexible curriculum to respond to industry's needs and student interests.*
- *That WPI invest in and expand its globalization programs across the curriculum.*
- *We confirm the work of the Commission on Innovative Graduate Education and, in addition, recommend that WPI's graduate programs incorporate a global perspective throughout the curriculum. This may be accomplished through internships, such as graduate co-op experiences, or through internships within industries that have global interactions.*
- *That our existing co-op programs and internships be redefined and expanded. Furthermore, we see international internships as a distinct advantage that could help WPI take a leadership position in setting the course for a globally oriented, technologically based education for the nation.*
- *That the continuing education program be expanded and strengthened. We also recommend that WPI investigate the potential for a part-time undergraduate program for the adult-learner sector of our society.*
- *That WPI's programs have flexibility and be responsive to student program needs.*

We can summarize by the following:

WPI of the 21st century must take advantage of its strength in technology and broaden along technical lines. It must be sensitive to the needs of its customers, both with respect to educational needs and financial needs. It must be flexible programmatically to meet these needs and to produce a higher-quality program at a lower consumer cost. The WPI faculty, administration and staff must respond rapidly and effectively to focused education initiatives. The institution must be prepared to provide resources. The administration, faculty and staff must work as a team to successfully respond to these initiatives.

The truly exciting aspect of these recommendations is the focus they place on the major thrusts of WPI's strategic plan. The challenge, however, is that while these recommendations will clearly increase WPI's attractiveness, they may act more to protect existing enrollments and revenue than to generate additional net revenue. And nearly all of the recommendations call for more resources. In the absence of additional revenue, the Institute will have to fund their implementation by reallocating resources from existing, presumably lower-priority activities, with some of the one-time start-up costs perhaps being funded by the Board of Trustees as "bridge investments."

Provost Diran Apelian has assigned the role of coordinating the development of specific implementation plans consistent with the BRTF recommendations on academic experience to Lance Schachterle, associate dean for undergraduate studies. Schachterle will seek the advice of the faculty's Committee on Governance to determine the most productive roles for the various faculty governance committees, individual faculty members, staff, students and the relevant administrative officers and offices in this process.

A key requirement of these implementation plans will be corresponding business plans that specify the requisite capital (space and equipment) and start-up resources. These business plans must also forecast the revenues and operating expenses from initiation to steady state. The provost will appoint an advisory group of governance committee chairs, the secretary of the faculty and an academic department head to assist in prioritizing these various implementation plans as they compete for resources. Some or all of these plans may well become candidates for the type of bridge investments proposed by the BRTF.

The BRTF presented its recommendations in this category under the headings of Cost Containment, Enhancing Net Revenue and Capital Expenditures:

Cost Containment

- *That the faculty and administration develop a process to significantly and continuously improve the effectiveness and efficiency of the educational process at WPI.*
- *That our existing programs be critically reviewed not only with respect to quality, but also to cost containment.*
- *That the goal of any new academic program initiatives be an educational cost less than that incurred by our traditional engineering and science programs.*
- *That the trustees review and consider the concept of a severance plan.*

The creation of a provost's advisory group on the implementation of BRTF recommendations, as outlined on page 7, speaks to the intent and letter of these process recommendations. Diran Apelian had previously inaugurated a process for periodic external review of the quality of our existing programs. In view of the BRTF recommendations, the implementation of this review process will be accelerated and an emphasis on cost effectiveness will be added to the charge.

The results of these studies will be reviewed by the same provost's advisory group, since existing programs compete for resources with proposed new academic initiatives. The advisory group will be cognizant of the BRTF recommendation regarding lower educational cost for new academic program initiatives.

As noted in the BRTF's report, the firm of William M. Mercer is working with a task force subcommittee and with administrative officers to propose a severance plan. The objective is to provide alternatives to senior faculty—and possibly staff—who wish to consider other career options. The task force subcommittee envisioned that this process could facilitate adjusting to changing conditions and priorities or attracting new colleagues at relatively little net cost.

Enhancing Net Revenue

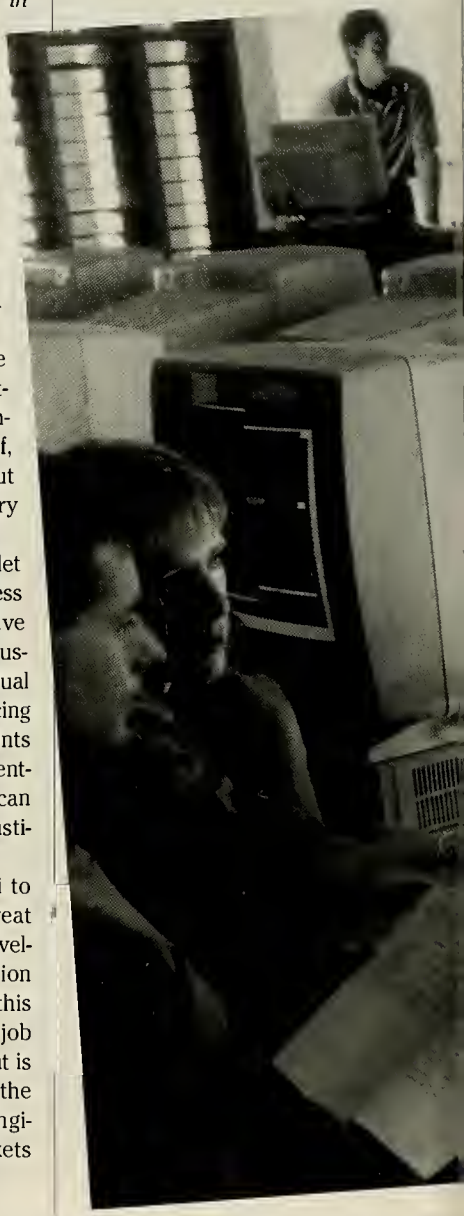
- *That the trustees retain the marketing firm of Barton and Gillet to determine what new skills and disciplines will be needed in the future so that WPI can offer new and broader career opportunities to its students.*
- *That the trustees retain Barton and Gillet to determine the demand for the program options outlined above.*
- *That WPI continue its current financial aid policy at least until the implementation of new academic programs, and the markets they are aimed at, provide the opportunity for different financial aid strategies. Further, that in the meantime the administration continue to study innovative financial aid approaches, such as the funding of WPI loans to students on a structured payback basis.*
- *That the administration develop proactive means, including more effective use of alumni, to enhance the image and profile of WPI graduates in the eyes of prospective employers in order to maintain a successful job placement record as an advantage in attracting prospective students.*

Barton-Gillet has been retained to see how receptive the prospective student marketplace might be to the BRTF recommendations regarding the academic experience. Further, they have been encouraged to provide advice on the much more difficult issue of how best to match WPI's considerable strengths with the perceived needs of the marketplace.

The scope of this study will also include continuing education, nontraditional and part-time undergraduate students. A client committee of key faculty and administrative staff, chaired by the provost, will coordinate input and review progress of this study. Preliminary results are expected this fall.

Another important focus of the Barton-Gillet study will be the comparative cost effectiveness of our financial aid policies. New comparative data analysis capabilities make it possible to custom tailor financial aid to the needs of individual market segments, thereby optimizing net pricing attractiveness. Given the relatively large amounts of money involved in financial aid, small percentage improvements mean large savings that can be employed to strengthen other aspects of institutional attractiveness.

At the 1993 Reunion, I challenged alumni to help us with job placement, and I found great receptivity. The Alumni Office, the Career Development Center and the WPI Alumni Association have begun working more closely to mobilize this interest in helping us develop more effective job placement programs. Successful job placement is a requisite for technological education, and the dramatic change in the demand for new engineers and scientists in our traditional markets requires new strategies and tactics.

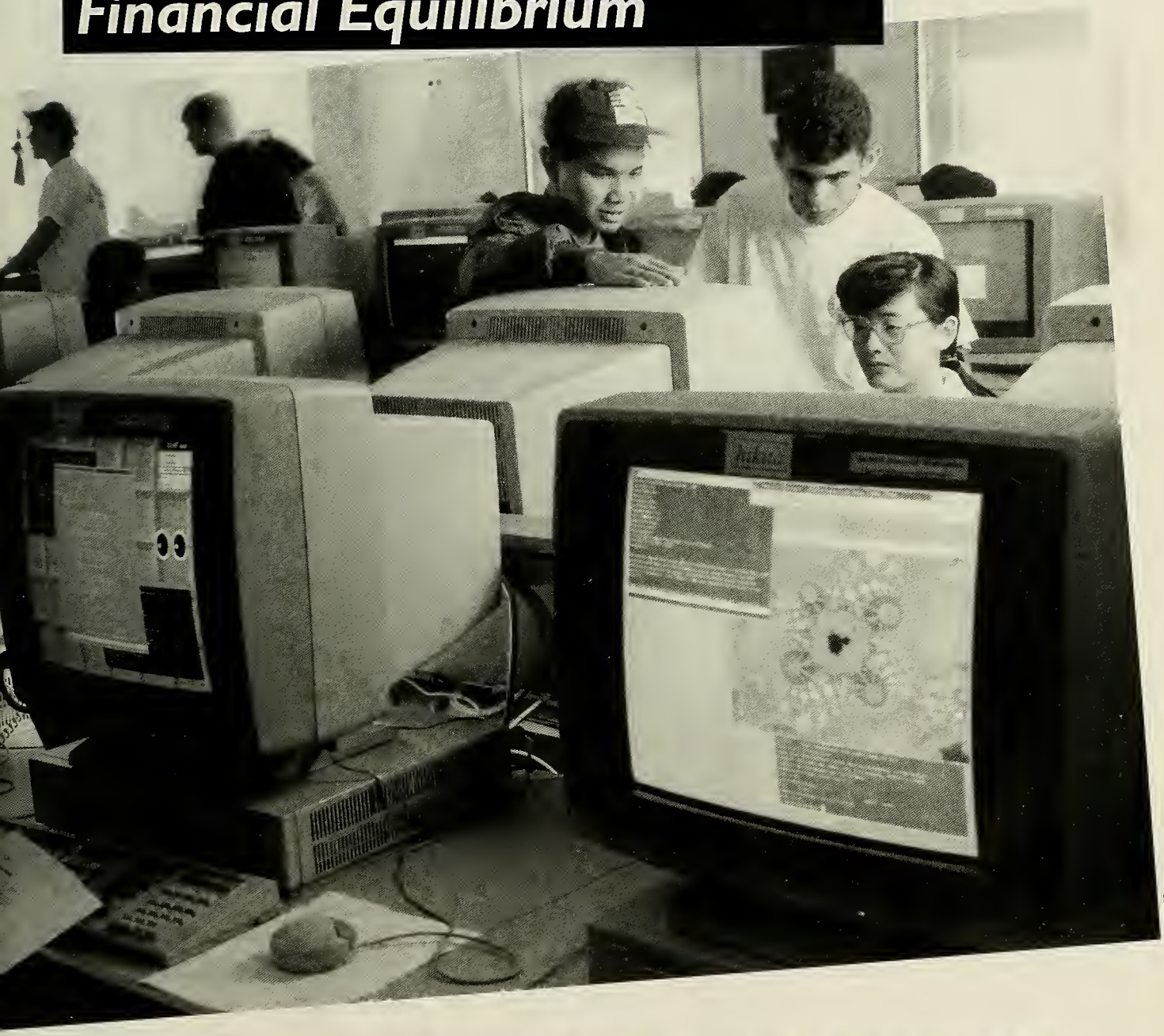


Capital Expenditures

- *That...major construction be financed by capital funds obtained through development efforts so that acquisition costs are not funded by the operating budget.*
- *That the trustees spend an appropriate amount each year on deferred maintenance to maintain the existing discipline now being applied to our physical assets.*

The trustees are committed to funding any new capital construction so as to minimize any dependence on the operating budget and are quite sensitive to the need to reduce deferred maintenance.

Financial Equilibrium



LOU JONES

"WPI in the 21st century must be financially stable. All institutions of higher education face and will continue to face ever-increasing pressures to deliver high-quality education at a substantially reduced cost to both the institution and the consumer."

The cost of delivering a superior technology-based education in engineering and science is high and growing higher all the time. The Blue Ribbon Task Force recommended that WPI work toward financial equilibrium by critically examining the costs and efficiencies of delivering academic programs, better matching its program offerings to the demands of the marketplace, exploring new approaches to financial aid, and financing major new construction solely through development efforts.

The Next Phase

The BRTF ended its report by focusing on the process going forward. Here are the recommendations from that section:

- *The task force recommends that as a critical strategic effort, the process continues to full conclusion, in accord with the president's charge. We further recommend that the follow-up phases be organized and assigned by the administration to appropriate groups, keeping in mind the necessity to maintain community involvement and collegiality in the process.*
- *The task force strongly recommends that the concepts presented, especially as they relate to broadening of our programs, be validated by the marketplace. We recommend that the firm of Barton and Gillet be commissioned to conduct a market study of our programmatic recommendations during the summer of 1993. Their charge should be to validate the concepts and recommendations we have made to broaden our scope and to specifically forecast the market acceptance and resource requirements of competing alternatives.*
- *We recommend that the WPI Board of Trustees reaffirm its commitment to make an appropriate bridge investment in support of the implementation of the comprehensive plan ultimately resulting from this process.*

As I've already suggested, follow-up phases have been organized and assigned to appropriate groups. The Community Council will assure that community involvement and collegiality are maintained. Every effort will be made to structure specific action steps so that they qualify for the bridge investments recommended to the trustees. These investments could come from capital assets (endowment), development activities or a combination of the two.

The WPI community owes the Blue Ribbon Task Force a great debt of gratitude for reaffirming so clearly the difficult financial and attitudinal environment in which we operate, and for suggesting so succinctly approaches to the comprehensive plan we seek for the future. The 1993-94 academic year promises to be particularly exciting as we involve every member of the WPI family in this process.

MICHAEL OORSEY

"Quality in all we do is essential to our continuing success. WPI must take advantage of its strengths in technology and broaden along technical lines; be sensitive to the needs of its customers, both financially and educationally; be flexible programmatically to meet their needs; and produce a higher quality program at a lower consumer and institutional cost."

At Reunion in 1993, President Strauss enlists alumni in the process of reshaping WPI for the 21st century. In the months ahead, all sectors of the WPI community will make their voices heard as the Institute maps out a comprehensive plan for the future.

FINANCIAL SUMMARY

By Robert W. Gailey
Vice President for Business Affairs
and Treasurer

WPI's financial position at June 30, 1993, continues to be strong. Led by the Endowment Fund, the Institute's investments and fund balances are at all-time highs. The Endowment Fund realized an increase in balance of $12.2 million for the year.

Total assets increased by approximately $16.3 million, or 7.7 percent, to $211 million, while total liabilities decreased slightly. Debt service (principal and interest) represented only 5.1 percent of unrestricted current fund expenditures and mandatory transfers for the year, which is comparatively low for educational institutions. Investments in property, plant and equipment—less accumulated depreciation—increased by 3.6 percent to $51.8 million.

The 11.4 percent increase in the book value of the Endowment Fund was due to new gift additions ($4 million), transfers from other funds ($360,000), and net reinvested returns ($7.8 million). The market value of the fund was $127,897,992 as of June 30, 1993. It produced an annual total return (net of fees) of 11.9 percent. This total return compared with the Standard and Poor's stock index gain of 13.6 percent and the Shearson Lehman intermediate bond index gain of 10.5 percent.

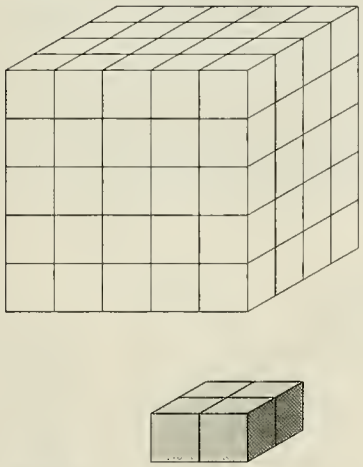
Total Current Fund revenue increased by $5.2 million in fiscal year 1993 to a total of $78 million; this represented a gain of 7.1 percent over fiscal year 1992. There was a positive bottom line from operations for the fiscal year of $18,401. The Institute increased its overall fiscal position (total fund balance) by $17 million, an 11 percent gain for the year.

Total funds expended for instruction and departmental research represented 34 percent of unrestricted educational, general and auxiliary revenue. While the annual funds expended for operation and maintenance of the physical plant increased by 4.9 percent, accumulated deferred maintenance on the WPI campus continued to total about $15 million.

Student aid awarded from unrestricted current funds increased by 16.9 percent to more than $10.1 million; it represented 22.6 percent of the total revenue (including room and board) collected from undergraduate students. Sponsored research and other sponsored programs increased by 35.9 percent to $9.1 million. This substantial increase resulted from a full year's activity by the Center for High Performance Computing.

While auxiliary operations (housing, food service, bookstore, etc.) generated $6.3 million in revenue, the cost to generate that revenue ran slightly more. The Institute's policy of operating auxiliary services on a self-supporting basis was essentially maintained.

Total Expenditures
(percent)



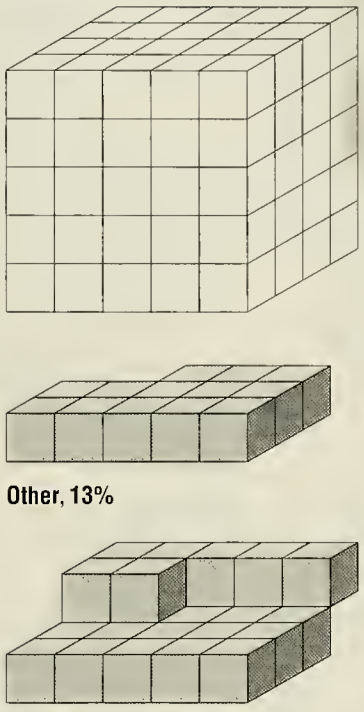
Other, 4%

Physical plant, computing and other administrative, 16%

Student Aid, 21%

Direct expenses for educational and research operations, 59%

Total Revenue
(percent)



Other, 13%

Endowment income, gifts and other internal revenue, 20%

Tuition, room and board, educational and other fees, 67%

FINANCIAL HIGHLIGHTS

YEARS ENDED JUNE 30, 1993 AND 1992

1. General Operating Funds (Thousands of Dollars)	1993	1992	Percent Change
Tuition, fees and other educational revenues	$46,311	$44,772	+3.4
Student financial aid	15,885	13,920	+14.1
Gifts, grants and bequests, as recognized	8,193	6,597	+24.2
Revenues from sponsored research programs	9,109	6,701	+35.9
Total staff benefit expenses, before allocation	6,930	6,253	+10.8

2. Endowment and Similar Funds (Thousands of Dollars)	1993	1992	Percent Change
Beginning market values	$114,757	$107,041	+7.2
plus:			
Investment results			
Income (interest and dividends)	$5,013	$5,934	
Realized gains	8,754	2,193	
Change in unrealized gains	3,636	3,762	
Total investment results	$17,403	$11,889	+46.4
less:			
Used in support of college	(3,996)	(3,963)	+0.8
Transferred to restricted funds	(266)	(1,900)	-86.0
Net reinvested in endowment	13,141	6,026	+111.7
plus:			
Additions to endowments, mostly from gifts	4,389	1,690	+159.7
Ending Market Value	**$127,898**	**$114,757**	**+11.5**

Five-Year Summary of Total Return Data	'93	'92	'91	'90	'89
WPI Total Return	11.9%	12.4%	8.5%	5.0%	11.6%
WPI Policy Index	13.5	13.5	8.7	13.7	17.1
S&P 500	13.6	13.5	7.4	16.4	20.5
Shearson Lehman Intermediate Bond	10.5	13.2	10.5	7.8	10.2
CPI Index	3.0	2.8	5.1	4.8	4.7

Copies of the complete audited financial reports for Worcester Polytechnic Institute for fiscal year 1993 can be obtained by writing to:

Office of Business Affairs
Worcester Polytechnic Institute
100 Institute Road
Worcester, MA 01609-2280

Financial Statements

Report of Independent Accountants

THE BOARD OF TRUSTEES
WORCESTER POLYTECHNIC INSTITUTE:

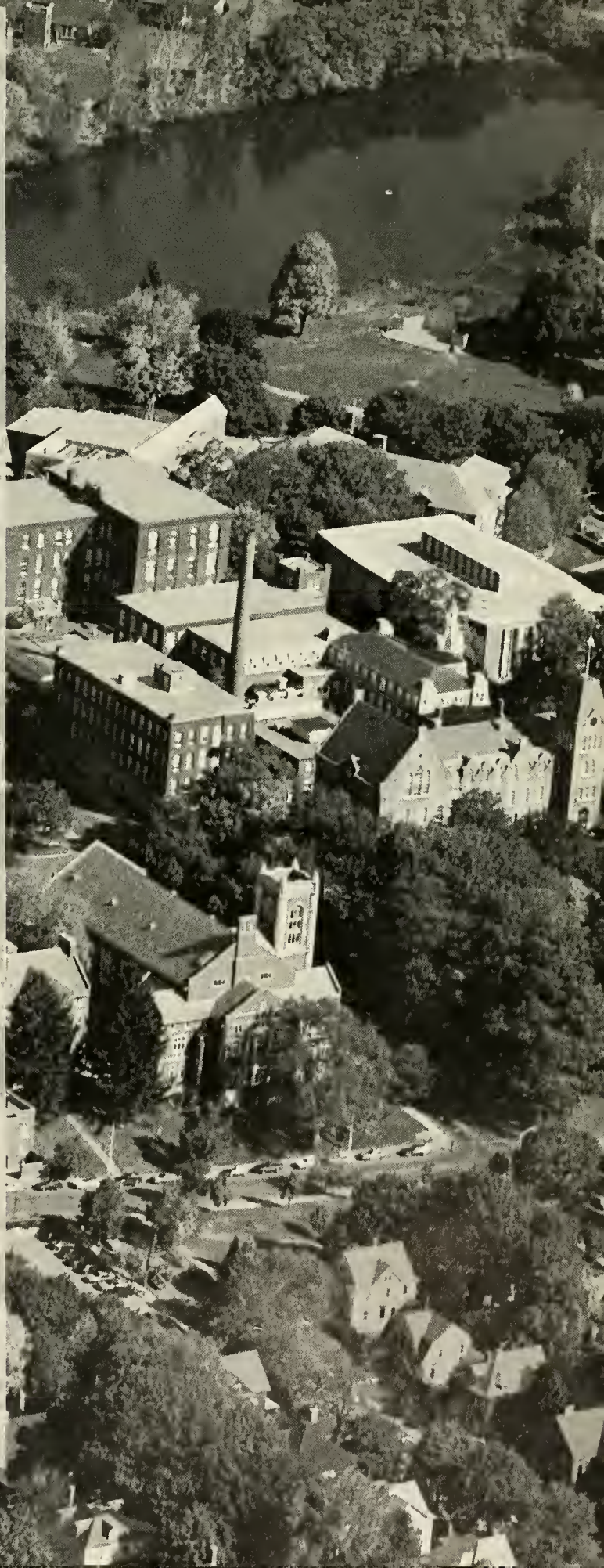
We have audited the accompanying balance sheet of Worcester Polytechnic Institute as of June 30, 1993 and the related statements of changes in fund balances and of current fund revenues, expenditures and other changes for the year then ended. We previously audited and reported upon the financial statements of Worcester Polytechnic Institute for the year ended June 30, 1992, for which condensed statements are presented for comparative purposes only. These financial statements are the responsibility of Worcester Polytechnic Institute's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with generally accepted auditing standards. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for our opinion.

In our opinion, the financial statements referred to above present fairly, in all material respects, the financial position of Worcester Polytechnic Institute as of June 30, 1993, the changes in its fund balances and its current fund revenues, expenditures and other changes for the year then ended in conformity with generally accepted accounting principles.

Coopers & Lybrand

Boston, Massachusetts
September 10, 1993



Audited Reports

Balance Sheet

June 30, 1993
(with comparative totals at June 30, 1992)

ASSETS	Current Funds Unrestricted	Current Funds Restricted	Loan Funds	Endowment and Similar Funds	Trust and Life Income Funds	Plant Funds	Total All Funds 1993	Total All Funds 1992
Cash and cash equivalents	$ 860,752	$ 63,350	$ 98,934				$ 1,023,036	$ 2,052,834
Investments, at cost (Note 4)	8,683,072	2,252,063	180,719	$ 120,905,954	$ 5,525,364	$ 4,530,729	142,077,901	125,321,055
Accounts receivable, net (Note 2)	982,561	2,315,430			37,776	873	3,336,640	4,779,835
Notes receivable (Note 3)	39,593		11,568,322				11,607,915	10,962,289
Inventories	21,792						21,792	68,013
Deposits with trustees (Note 6)						455,330	455,330	493,102
Property, plant and equipment, net (Note 5)						51,249,488	51,249,488	49,615,275
Construction in progress						581,347	581,347	437,026
Prepaid expenses	64,726						64,726	334,029
Deferred financing costs (Note 1)						1,003,480	1,003,480	1,056,051
Interfund balances, net (Note 1)	(5,477,315)	6,458,075	(2,046,713)	(1,651,757)	(53,499)	2,771,209	—	—
Total assets	**$5,175,181**	**$11,088,918**	**$ 9,801,262**	**$119,254,197**	**$5,509,641**	**$60,592,456**	**$211,421,655**	**$195,119,509**
LIABILITIES AND FUND BALANCES								
Liabilities:								
Accounts payable	783,956	377,767	58	5,490		88,042	1,255,313	1,344,150
Accrued expenses	1,928,257			12,975		668,587	2,609,819	2,733,557
Annuities payable (Note 1)					1,086,293		1,086,293	885,201
Deposits and deferred revenue	1,708,458						1,708,458	1,606,965
Funds held for others		128,875			90,833		219,708	157,491
Long-term debt (Note 6)						34,163,774	34,163,774	35,020,673
Commitments (Note 9)								
Total liabilities	**4,420,671**	**506,642**	**58**	**18,465**	**1,177,126**	**34,920,403**	**41,043,365**	**41,748,037**
Fund balances:								
Unrestricted	754,510						754,510	736,109
Restricted		10,582,276	1,482,270	53,600,872	4,332,515		69,997,933	61,297,794
Internally designated				65,634,860			65,634,860	60,834,556
Plant Fund						25,672,053	25,672,053	22,311,230
U.S. Government			8,318,934				8,318,934	8,191,783
Total fund balances	**754,510**	**10,582,276**	**9,801,204**	**119,235,732**	**4,332,515**	**25,672,053**	**170,378,290**	**153,371,472**
Total liabilities and fund balances	**$5,175,181**	**$11,088,918**	**$ 9,801,262**	**$119,254,197**	**$5,509,641**	**$60,592,456**	**$211,421,655**	**$195,119,509**

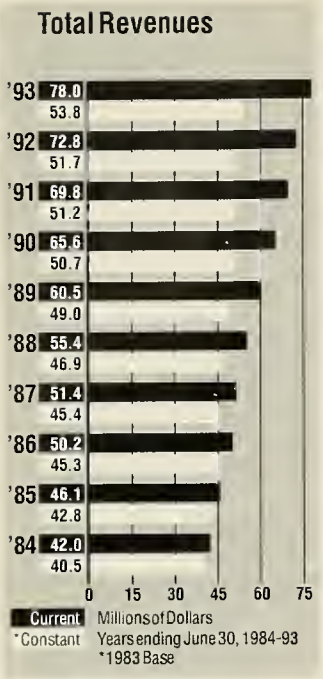
The accompanying notes are an integral part of the financial statements.

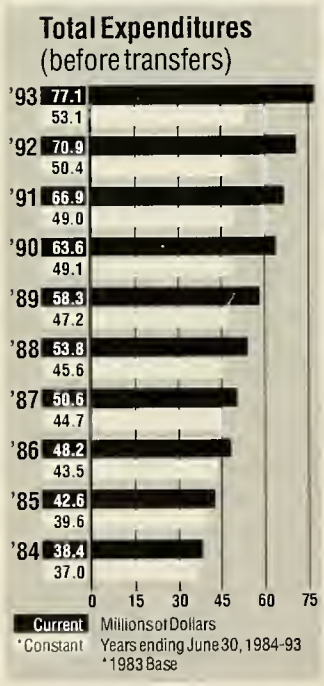
Statement Of Changes In Fund Balances

June 30, 1993
(with comparative totals at June 30, 1992)

	Current Funds		Loan	Endowment and Similar	Trust and Life Income	Plant	Total All Funds	
	Unrestricted	Restricted	Funds	Funds	Funds	Funds	1993	1992
Revenues and other additions:								
Student tuition and fees	$41,748,891						$ 41,748,891	$ 39,966,948
Other educational operations	4,562,376						4,562,376	4,804,567
Auxiliary enterprises	6,257,508						6,257,508	6,349,002
Sales and services	25,410						25,410	38,543
Other operating sources	767,265						767,265	725,876
Endowment income	3,316,153	$ 1,663,762	$ 32,168	$ 17		$ 1,227	5,013,327	5,934,203
Investments and similar income	984,444	94,734	257,253		$ 159,138	499,592	1,995,161	1,764,387
Net realized gain on investments				8,753,643	125,942		8,879,585	2,254,833
Contracts, grants and financial aid	1,564,695	12,837,355	24,604				14,426,654	11,239,280
Gifts and other receipts	1,670,815	4,141,161		4,009,677	460,256	3,267,613	13,549,522	7,592,100
Other additions in funds		90,496	2,324	63,673		55,149	211,642	339,341
	60,897,557	**18,827,508**	**316,349**	**12,827,010**	**745,336**	**3,823,581**	**97,437,341**	**81,009,080**
Expenditures and other deductions:								
Current fund expenditures	56,912,284	17,149,519					74,061,803	68,251,452
Cancellation of principal and interest on student loans			10,431				10,431	41,301
Depreciation						3,954,317	3,954,317	3,499,400
Interest on indebtedness						2,217,893	2,217,893	2,492,387
Administrative and custodial fees			120,220		38,768		158,988	157,755
Other financing charges							—	879,289
Other deductions in funds					27,091		27,091	163,026
	56,912,284	**17,149,519**	**130,651**	**—**	**65,859**	**6,172,210**	**80,430,523**	**75,484,610**
Transfers between funds:								
Mandatory:								
Principal and interest	(3,053,978)					3,053,978	—	—
Nonmandatory:								
Funded depreciation (Note 5)	(1,481,094)	(200,000)				1,681,094	—	—
Investment earnings transferred (to) from endowment	680,462	303,767	6,464	(990,939)		246	—	—
Unrestricted gifts allocated	(379,000)			379,000			—	—
Repair and replacement reserve	(161,679)					161,679	—	—
Other transfers (Note 5)	428,417	(1,220,857)		(20,015)		812,455	—	—
	(3,966,872)	**(1,117,090)**	**6,464**	**(631,954)**	**—**	**5,709,452**	**—**	**—**
Net increase in fund balance	18,401	560,899	192,162	12,195,056	679,477	3,360,823	17,006,818	5,524,470
Beginning fund balance	736,109	10,021,377	9,609,042	107,040,676	3,653,038	22,311,230	153,371,472	147,847,002
Ending fund balance	**$ 754,510**	**$10,582,276**	**$9,801,204**	**$119,235,732**	**$4,332,515**	**$25,672,053**	**$170,378,290**	**$153,371,472**

The accompanying notes are an integral part of the financial statements.





Statement Of Current Fund Revenues, Expenditures And Other Changes

for the year ended June 30, 1993
(with comparative totals for the year ended June 30, 1992)

	Current Funds		Total Current Funds	
	Unrestricted	Restricted	1993	1992
Revenues:				
Educational and general:				
Student tuition and fees	$41,748,891		$ 41,748,891	$ 39,966,948
Other educational operations	4,562,376		4,562,376	4,804,567
Sales and services	25,410		25,410	38,543
Other operating sources	767,265		767,265	725,876
Endowment, investment and similar income	4,300,597	$ 1,518,383	5,818,980	6,669,635
Contracts, grants and gifts	3,235,510	15,631,136	18,866,646	14,283,025
	54,640,049	17,149,519	71,789,568	66,488,594
Auxiliary operations	6,257,508	—	6,257,508	6,349,002
Total revenue	**60,897,557**	**17,149,519**	**78,047,076**	**72,837,596**
Expenditures:				
Educational and general:				
Instruction and department research	18,684,508	2,037,255	20,721,763	20,635,059
Library	1,424,996	538	1,425,534	1,467,538
Student services	2,981,635	191,700	3,173,335	2,927,140
Public services and information	1,663,636	39,405	1,703,041	1,711,957
Operation and maintenance of plant	5,105,293	17,239	5,122,532	4,884,892
General administrative and institutional	3,145,556	7,732	3,153,288	2,830,412
Staff benefits	5,972,436		5,972,436	5,429,565
Student aid	10,138,743	5,746,311	15,885,054	13,919,989
Sponsored research and other sponsored programs		9,109,339	9,109,339	6,701,131
Other educational operations	1,717,652		1,717,652	1,802,884
College computer center	1,383,308		1,383,308	1,271,805
	52,217,763	17,149,519	69,367,282	63,582,372
Mandatory transfer for principal and interest	1,402,859		1,402,859	1,131,059
Total educational and general and mandatory transfer	**53,620,622**	**17,149,519**	**70,770,141**	**64,713,431**
Auxiliary expenditures:				
Expenditures	4,694,521		4,694,521	4,669,080
Mandatory transfer for principal and interest	1,651,119		1,651,119	1,505,542
Total auxiliary expenditures and mandatory transfer	**6,345,640**	**—**	**6,345,640**	**6,174,622**
Total expenditures and mandatory transfers	**59,966,262**	**17,149,519**	**77,115,781**	**70,888,053**
Excess of restricted receipts over revenue transfers		1,677,989	1,677,989	2,791,176
Nonmandatory transfers:				
Investment earnings transferred (to) from endowment (Note 4)	680,462	303,767	984,229	(71,028)
Funded depreciation	(1,481,094)	(200,000)	(1,681,094)	(1,693,269)
Repair and replacement reserve	(161,679)		(161,679)	(130,155)
Unrestricted gifts allocated	(379,000)		(379,000)	(5,830)
Other transfers	428,417	(1,220,857)	(792,440)	(2,953,163)
Nonmandatory transfers	(912,894)	(1,117,090)	(2,029,984)	(4,853,445)
Net increase (decrease)	18,401	560,899	579,300	(112,726)
Beginning fund balance	736,109	10,021,377	10,757,486	10,870,212
Ending fund balance	**$ 754,510**	**$10,582,276**	**$11,336,786**	**$10,757,486**

The accompanying notes are an integral part of the financial statements.

Notes To Financial Statements

1. Accounting Policies:

Basis of Presentation The accompanying financial statements have been prepared on the accrual basis of accounting. The statement of current fund revenues, expenditures, and other changes is a statement of financial activities of current funds related to the current reporting period. It does not purport to present the results of operations or the net income or loss for the period as would a statement of income or a statement of revenues and expenses.

To the extent that current funds are used to finance plant assets, the amounts so provided are accounted for as (1) expenditures, in the case of normal replacement of movable equipment and library books; (2) mandatory transfers, in the case of required provisions for debt amortization and interest and equipment renewal and replacement; and (3) transfers of a nonmandatory nature for all other cases.

Gifts and pledges are recorded when collected. Fair value is assigned on the date of receipt. During 1993, gifts-in-kind of $3,267,613 were recorded in the plant fund.

Fund Accounting In order to ensure the observance of limitations and restrictions placed on the use of the resources available to Worcester Polytechnic Institute (the "Institute"), the accounts of the Institute are maintained in accordance with "fund accounting" principles. This is the procedure by which resources for various purposes are classified for accounting and reporting purposes, into funds that are in accordance with activities or objectives specified. Separate accounts are maintained for each fund; however, in the accompanying financial statements, funds that have similar characteristics have been combined into fund groups. Accordingly, all financial transactions have been recorded and reported by each respective fund group.

Within each fund group, fund balances restricted by outside sources are so indicated and are distinguished from unrestricted funds allocated to specific purposes by action of the governing board. Externally restricted funds may only be utilized in accordance with the purposes established by the source of such funds and are in contrast with unrestricted funds over which the Institute retains control to use in achieving any of its institutional purposes.

Fund Groups The assets, liabilities and fund balances of the Institute are reported in five self-balancing fund groups.

1. **Current funds** include all unrestricted and restricted resources that are available for operating purposes of performing the primary missions of the Institute.
2. **Loan funds** are restricted for use in making loans to students and include resources received from donors, governmental agencies and mandatory institutional matching grants.
3. **Endowment funds** include the following: (1) true endowment funds that are subject to restrictions of the gift instruments requiring the principal be invested in perpetuity with only the income to be expended, and (2) internally designated endowment funds that are established by the governing board to act as endowments where the principal, as well as the income, may be expended.
4. **Trust and Life Income Funds** consists of funds acquired by the Institute subject to agreements whereby assets are made available to the Institute on the condition that the Institute bind itself to pay stipulated amounts periodically to designated individuals. Payments of such amounts terminate at a time specified in the agreements.
5. **Plant funds** are used to account for the transactions relating to investment in the Institute's properties.

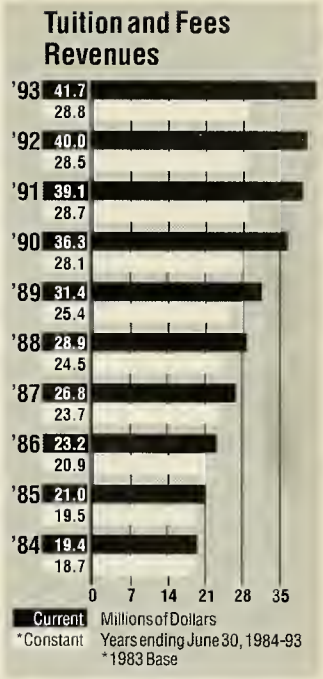
All gains and losses arising from the sale, collection or other disposition of investments and other noncash assets are accounted for in the fund that owned such assets. Ordinary income derived from investments, receivables and the like is accounted for in the fund owning such assets, except for income derived from investments of endowment and similar funds, which income is accounted for in the fund to which it is restricted or, if unrestricted, as revenues in unrestricted current funds.

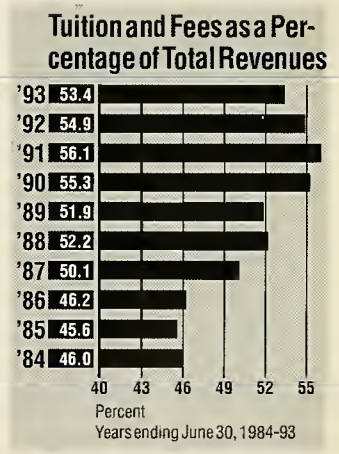
All other unrestricted revenue is accounted for in the unrestricted current fund. Restricted gifts, grants, appropriations, endowment income and other restricted resources are accounted for in the appropriate restricted funds. Restricted current funds are reported as revenues and expenditures when expended for current operating purposes.

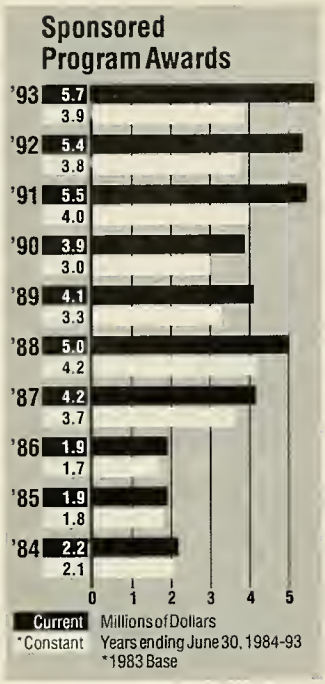
Cash and Cash Equivalents Cash and cash equivalents include cash on hand and short-term investments, principally the Common Fund Intermediate Cash Fund, which consist principally of U.S. government agency obligations.

Inventories Inventories, consisting principally of personal computer equipment, are valued at the lower of cost (first-in, first-out) or market.

Interfund Borrowings and Advances The interfund borrowings and advances are temporary in nature except for $2,046,713 payable from the student loan fund to the current fund. The payable to the current fund is expected to be paid from specific loan collections within a 10-year period without interest.







Deferred Financing Costs Deferred financing costs relate to debt issuance costs that are amortized over the life of the bonds. Total amortization expense for each of the years ended June 30, 1993 and 1992, were $58,573 and $56,363, respectively.

Sponsored Research In October 1991, the Board of Trustees voted to approve the establishment of the Center for High Performance Computing (the "Center"). The nucleus group of engineers and computer scientists that comprise the basis of the Center previously worked on government supported contract research for Encore Computer Corporation. On Nov. 18, 1991, the Center began operations under active U.S. government agency contracts specifically awarded to WPI. Commencing on Nov. 18, 1991, the revenue, expenses and balance sheet accounts of the Center are included in the financial statements of the Institute.

Revenues associated with research and other contracts and grants at both the Institute and the Center are recognized as related costs are incurred. Indirect cost recovery by the Institute on U. S. government agency contracts and grants is based upon a predetermined fixed rate. The Center has been operating under a negotiated fixed provisional indirect cost recovery rate negotiated with the principal U.S. government agency and is subject to the results of an impending audit.

Total sponsored research revenue recognized in restricted current funds in fiscal 1993 and 1992 amounted to:

	1993	1992
The Institute	$ 3,902,921	$ 4,254,927
The Center	5,206,418	2,446,204
Total sponsored research revenue	**$9,109,339**	**$6,701,131**

Property, Plant and Equipment Land and land improvements, buildings, and equipment are recorded at cost at the date of purchase. When assets are retired or otherwise disposed of, the cost and related accumulated depreciation are removed from the accounts, and any resulting gain or loss is reflected in operations for the period. The cost of maintenance and repairs is charged to income as incurred; significant renewals and betterments are capitalized.

The Institute depreciates capital assets based upon their useful lives. The policy applies to assets acquired with an expected useful life of three years or more and a cost greater than $500. Depreciation is calculated using the straight-line method, half-year convention over the following estimated useful lives:

Land improvements .....10 - 20 years
Buildings and improvements .....20 - 50 years
Equipment.....3 - 10 years

Annuities Payable Amounts due to donors in connection with gift annuities is determined based on remainder value calculations that generally assume a rate of return of 10 percent, maximum payout terms of 20 years, and an interest payout rate of 7.5 percent.

Vested Vacation Accrual The Institute accrues a liability for estimatable compensated absences (vested vacation for hourly and salaried employees) as required by FASB Statement No. 43.

Tax-Exempt Status The Institute is exempt from federal income tax under Section 501(c)(3) of the Internal Revenue Code.

Reclassification Certain amounts in the June 30, 1992, financial statements have been reclassified to conform with the June 30, 1993, presentation.

2. *Accounts Receivable:*

Accounts receivable consist of the following:

	1993 Current Funds		1992 Total Current Funds
	Unrestricted	Restricted	
Sponsored research		$ 2,000,030	$ 3,462,379
Other receivables	$1,005,561	315,400	1,339,150
	1,005,561	2,315,430	4,801,529
Less: allowance for doubtful accounts	23,000	—	23,000
Total accounts receivable	**$ 982,561**	**$2,315,430**	**$4,778,529**

At June 30, 1993, sponsored research accounts receivable related to the Center amounted to $673,410, which is net of an advance payment of $860,000.

3. Notes Receivable:

Notes receivable consist of the following:

	1993		1992 Total
	Current Fund	Loan Fund	Notes Receivable
Student loans		$ 11,584,171	$ 10,928,260
Other	$ 39,593	—	49,878
Less: allowance for doubtful accounts		15,849	15,849
Total notes receivable	**$39,593**	**$11,568,322**	**$10,962,289**

Notes receivable are principally amounts due from students under federally sponsored loan programs that are subject to significant restrictions. Accordingly, it is not practicable to determine the fair value of such amounts.

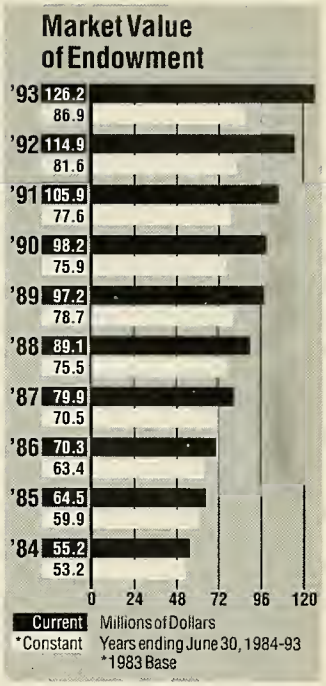
4. Investments:

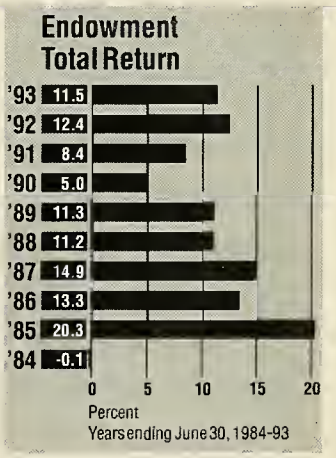
Investments are stated at cost. Investments acquired by gift or bequest are recorded at market value at the date of acquisition. Purchases and sales of investments are recorded on settlement date. Market value represents the fair value of investments at June 30, 1993. Realized gains and losses are accounted for within the fund that holds the investments using the specific identification method. Investment income is recorded when received. At June 30, 1993, short-term investments in the current unrestricted funds consisted of $3,000,000 in fixed-income mutual fund and commercial paper with maturities ranging from July 1993 to November 1993. There was no more than $1,000,000 invested in any single issuer of commercial paper. Investments of endowment and similar funds are composed of the following:

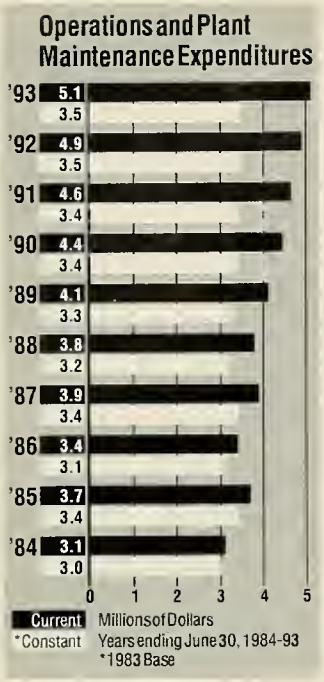
	Book Value		Market Value	
	1993	1992	1993	1992
Equities	$ 48,207,923	$ 29,671,932	$ 50,080,960	$ 29,329,536
Bonds	15,884,315	25,015,486	16,976,358	26,537,101
Short-term notes	15,213,692	2,165,130	15,214,992	2,165,130
Mutual funds:				
Equity funds	14,999,441	28,220,370	15,493,919	32,447,694
Fixed-income funds	15,328,086	13,900,623	18,391,297	15,908,498
Mortgages on real estate	27,792	46,423	27,792	46,423
Realty trust*	2,813,000	2,513,000	2,813,000	2,513,000
Oil and gas, L.P.*	6,000,000	3,450,000	6,000,000	3,450,000
Bioventures, L.P.*	1,724,518	1,259,933	2,192,487	1,631,322
Other	707,187	728,271	707,187	728,271
Total	**$120,905,954**	**$106,971,168**	**$127,897,992**	**$114,756,975**

* Not publicly traded.

Endowment Income and Spending Investments of endowment and similar funds, except for five funds with a combined market value of $3,613,596, are pooled on a market value per unit basis at the beginning of the calendar quarter within which a transaction takes place. At June 30, 1993, there was a total of 40,490,939 units, each having a market value of $3.028. Of the total units, 17,569,683 were owned by endowment funds and 22,921,256 were owned by internally designated funds.







The following tabulation summarizes changes in the relationship between cost and market values of the pooled investments:

	Pooled Investments			Market Value
	Market	Cost	Gains	Per Unit
June 30, 1993	$124,284,393	$117,634,503	$6,649,890	$3.028
June 30, 1992	111,341,624	103,644,369	7,697,255	2.857
Change in unrealized appreciation for year			(1,047,365)	
Net realized gains on pooled investments			8,828,808	
Less: realized gains on pooled investments distributed as investment income to the current fund			(990,939)	
Total net realized and unrealized gain for year			**$6,790,504**	**$ .171**

A summary of the market value per unit and the income per time-weighted unit for the pooled investments held as of June 30, 1993, and in each of the prior four years is as follows:

	Income Per Time-Weighted Unit	Market Value Per Unit
1993	$.121	$3.028
1992	.149	2.857
1991	.163	2.676
1990	.170	2.637
1989	.190	2.680

The Institute observes a spending rule with respect to unrestricted investment income on investments of the endowment and similar funds. In accordance with that spending rule, the Institute distributed 5.50 percent of the average unit market value for the previous two years to current operations.

The spending rule distribution for fiscal 1993 is .146 per time-weighted unit that was comprised of .121 of income per time-weighted unit and .025 per unit distributed from accumulated capital gains.

5. Property, Plant and Equipment:

Property, plant and equipment consists of the following:

	1993	1992
Land and land improvements	$ 4,370,848	$ 4,258,848
Buildings	58,890,108	57,441,189
Equipment	15,321,481	11,383,872
	78,582,437	73,083,909
Less: accumulated depreciation	27,332,949	23,468,634
	$51,249,488	**$49,615,275**

In fiscal 1993, the Institute funded $1,681,094, a portion of the depreciation expense, as a nonmandatory transfer from the current funds to the plant funds. Other transfers include $812,455 of gifts the Institute transferred relating to capital projects completed during the year from the restricted funds to the plant fund.

6. Long-Term Debt:

Long-term debt at June 30, 1993, amounted to $34,163,774. Schedule I summarizes the components of long-term debt. The aggregate amounts of principal due for each of the next five fiscal years are as follows:

1994	$ 902,288
1995	968,082
1996	1,034,309
1997	1,091,004
1998	1,158,004
	$5,153,687

On Oct. 1, 1988, the Institute deposited with Trustees sufficient funds to defease HEFA Series B Bonds, which mature July 1, 2000. The amount of Series B principal outstanding at June 30, 1993, was $5,285,000.

During fiscal 1992, the Institute issued $23,745,000 HEFA Series E bonds, which pay annual interest rates ranging from 6.0 percent to 6.75 percent and mature Sept. 1, 2001 through Sept. 1, 2017. Proceeds of the bonds were used to refund the $23,000,000 HEFA. Series D bonds, which had a fixed interest rate of 6.75 percent to March 1, 1992, and a variable rate thereafter until maturity at Sept. 1, 2018. The bonds are collateralized by pledged tuition receipts.

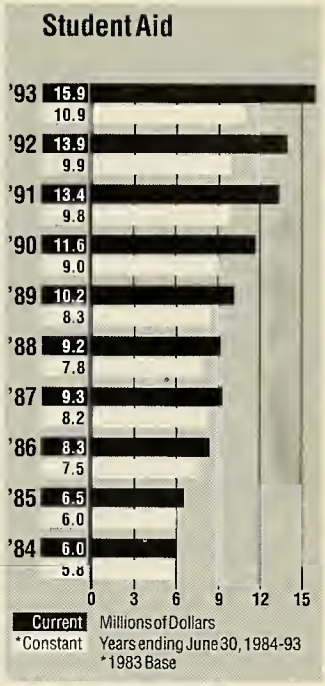
In compliance with the Institute's various bond indentures, deposits with Trustees at June 30, 1993, include investments in debt service and reserve funds of $455,330.

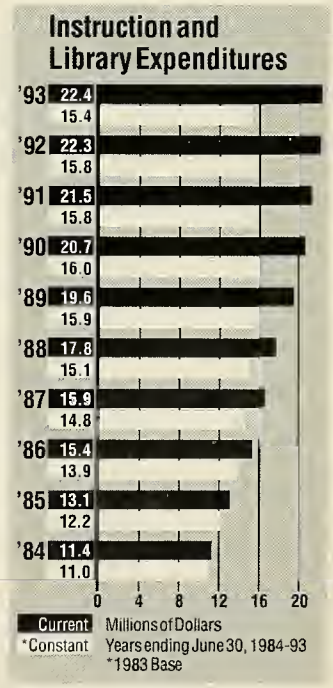
The bond agreements contain restrictive covenants that, among other restrictions, include the maintenance of certain financial ratios.

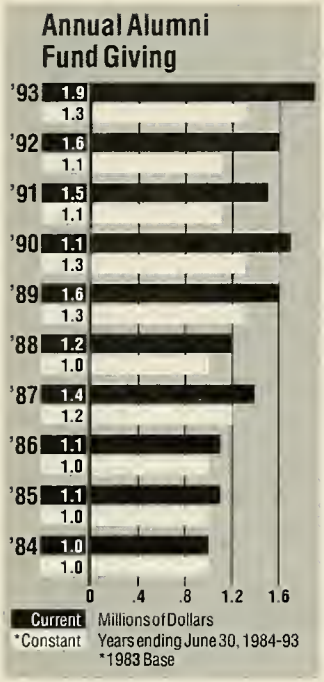
At June 30, 1993, the Institute had outstanding an interest rate swap agreement with an investment broker, having a total notional principal amount of $30,000,000. The agreement effectively changes the interest rate exposure on the Series C and E (see Schedule I, below) bonds to a variable rate based on a specified bond index, commencing in fiscal 1992 and terminating in fiscal 1997. The Institute is exposed to credit loss in the event of nonperformance by the other party to the interest rate swap agreement. However, the Institute does not anticipate nonperformance by the counterparty.

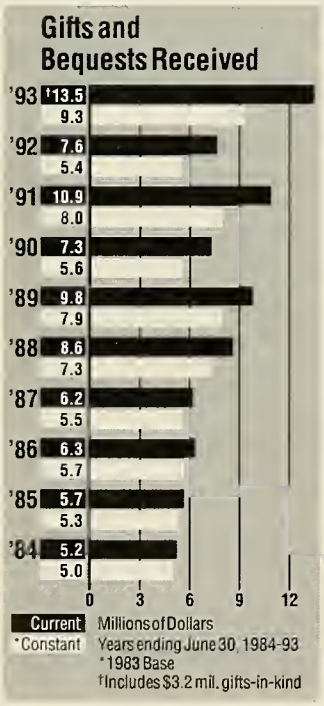
Schedule I. Summary of Bonds and Mortgages Payable, June 30, 1993

Purpose and Description	Maturity Date	Interest Rate %	Original Issue	Amount Due Within One Year	Balance, June 30, 1993
Bonds Payable:					
Housing and Urban Development:					
Series A - April 1, 1969 (1)	July 1, 1997	2 3/4	$ 987,000	$ 45,000	$ 237,000
Series B - April 1, 1969 (2)	July 1, 2001	3 3/8	919,000	35,000	324,000
Series C - April 1, 1969 (3)	July 1, 2019	3.0	1,160,000	20,000	817,000
				100,000	1,378,000
Massachusetts Health and Educational Facilities Authority:					
Series A - July 1, 1977 (4)	July 1, 2003	4.7-5.3	4,150,000	155,000	1,970,000
Series C - Oct. 1, 1988 (5)	Sept. 1, 2000	5.7-7.1	7,985,000	570,000	5,900,000
Series E - Dec. 1, 1991 (6)	Sept. 1, 2017	6-6.75	23,745,000	—	23,745,000
				725,000	31,615,000
Mortgages Payable:					
Ellsworth-Fuller Student Residence Center (7)	Dec. 31, 2003	7 1/4	1,950,000	77,288	1,170,774
				77,288	1,170,774
Total bonds and mortgages payable (8)				**$902,288**	**$34,163,774**









(1) Collateralized by land, building and equipment known as Morgan Hall (carried on the accounts at $907,388) and pledged net revenues from the operations of the dormitory and dining hall located therein.

(2) Collateralized by land, building and equipment known as Daniels Hall (carried on the accounts at $650,808) and pledged net revenues from the operations of the dormitory and bookstore located therein.

(3) Collateralized by land, building and equipment known as Stoddard Residence Center (carried on the accounts at $864,052) and pledged net revenues from the operations of the dormitory and health service located therein.

(4) Pledged as collateral are $2,167,000 of internally designated endowment funds equal to 110 percent of the principal amount of the bonds outstanding and are held by a Trustee in the Debt Service Reserve Fund. Various academic revenues are pledged as security for the HEFA Series A bonds.

(5) Various academic revenues are pledged as security for the HEFA Series C bonds.

(6) The bonds are collateralized by pledged tuition receipts.

(7) Interest is at 7 1/4 percent, of which 3 percent is paid by the Institute and the balance is paid by the U.S. Department of Housing and Urban Development.

(8) The total debt outstanding at June 30, 1993, approximates fair value based on estimates using current interest rates available for debt with the same remaining maturities.

7. Pension Plans:

The Institute contributes to a defined contribution plan (TIAA-CREF) for academic and nonacademic personnel. Contributions to TIAA-CREF are based on a percentage of payroll. The Institute's pension costs amounted to $2,058,090 and $1,886,501 for fiscal years ended 1993 and 1992, respectively.

8. Pledges Receivable:

As of June 30, 1993, management estimates that outstanding pledges approximate $7,902,000. The pledges are not included in the financial statements since it is not practicable to estimate the net realizable value of such pledges. Pledges consist primarily of restricted bequests that will be received at a future point in time.

9. Commitments:

The Institute is in the third year of an agreement with Endowment Realty Investors Inc. to purchase $3,000,000 of shares by June 30, 1994. This fund invests in commercial real estate nationwide. As of June 30, 1993, the Institute had purchased shares amounting to $2,813,000 and has a remaining commitment under the agreement of $187,000.

The Institute has guaranteed a $297,000 mortgage debt of a fraternity. The mortgage is collateralized by the property.

The Institute is obligated under noncancelable operating leases for various facilities and equipment. Assets under these lease agreements consist of office furniture, computer equipment, office space and storage facilities.

Commitments under noncancelable operating leases provide for minimum rental payments aggregating $682,700 for the five-year period ended June 30, 1998. Rental expense for the year ended June 30, 1993, was $326,272.

10. Contingencies:

The Institute has pending several cases that have arisen in the normal course of its operations. The Institute believes that the outcome of these cases will have no material adverse effect on the Institute's financial position.

The Institute's sponsored research program and indirect cost recovery are subject to future audits by the respective sponsoring federal agencies as provided for in federal sponsored research regulations. Management believes that such audits will not have a materially adverse effect on the Institute's financial position.

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As of June 30, 1993

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Numbers in parentheses indicate trustee committee appointments.

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(Assignments effective July 1, 1993)

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2. Audit
3. Budget and Finance
4. Development
5. Executive
6. Executive Compensation
7. Investment
8. Nominating
9. Physical Facilities
10. Trusteeship

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Vice President for Administration

Office of Acodemic Affairs

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School of Industriol Monogement

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Physics

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Social Science and Policy Studies

Year in Review

1992-93: Setting the Stage for the Future

By Jon C. Strauss

The work of the Blue Ribbon Task Force (BRTF) formed the centerpiece of an eventful year at Worcester Polytechnic Institute. In fact, the 365 days from July 1, 1992, to June 30, 1993, were filled with the kinds of accomplishments and milestones that not only advance the mission of the Institute, but set the stage for future growth and excellence.

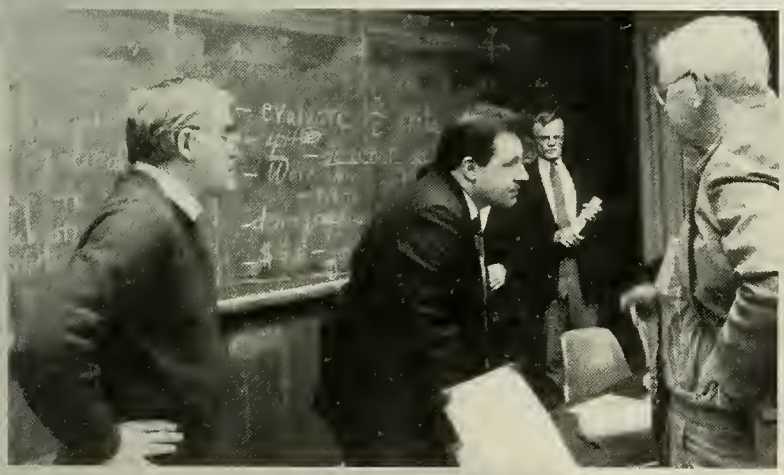
One of the more significant events of the year was the completion of an updated campus master plan by the firm of Earl R. Flansburgh & Associates. Flansburgh drafted a detailed campus plan in 1982 that provided the impetus for such campus improvements as Founders Hall, and also helped in the site selection for Fuller Laboratories.

The updated plan focused on four areas: facility needs in student residences, mechanical engineering space requirements, the feasibility of a proposed campus center, and issues surrounding parking on campus. While a plateau in student interest in residing on campus appears to have rendered the residence question moot (at least in the short term), significant interest has been demonstrated in the other three areas.

The Blue Ribbon Task Force Report spoke directly to the issues of the campus center and parking (see article on page 3). In addition, good progress has been made on the mechanical engineering project. Preliminary plans have been drafted for a renovation of Higgins Laboratories that should provide the needed upgrade of existing space and the addition of new space for research, education and project work. At the same time, funding for the project is reaching a critical mass.

On April 22, 1993, the George I. Alden Trust announced its gift of $2.4 million for the Higgins renovation. The gift, announced during a celebration on campus of the 150th birthday of Alden, the Institute's first professor of mechanical engineering, was the largest ever made by the trust and the second largest gift ever received by WPI. With earlier gifts, which total some $2.5 million, with outstanding proposals to national foundations seeking some $1.6 million, and with the solid prospect of anniversary class gifts to make up the difference, the bulk of the funding for this project could soon be in hand.

What follows is a summary of some of the other significant accomplishments of the 1992-93 academic year. These are grouped under the headings of the six goals of the Institute's strategic plan, illustrating the progress we continue to make toward reaching those overarching targets.



NEIL NORUM

DENNIS VANDAL

Above, from left, Blue Ribbon Task Force members Raymond Hagglund and Albert Sacco listen to members of the audience after an open meeting in the spring of 1992. Task force member and WPI trustee Peter Horstmann is in the background. Right, Clarkson University President Richard Gallagher addresses guests at the Alden Celebration. The great hall of Alden Memorial forms the background for this page.

Students register at the start of another academic year in August 1992. From a grant to develop a new model of education based on collaborative learning, to new developments in globalization, to major curricular reviews in several departments, WPI's undergraduate program was an important focus of activity in 1992-93.

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Goal 1: Enhance the Level of Excellence in Undergraduate Education

- The combined B.S./D.V.M. program that WPI established with Tufts University School of Veterinary Medicine in 1992 yielded 14 freshmen for 1993-94, up from five for its first year of operation. The program enables a student to earn admission to both WPI and Tufts while still a senior in high school.
- A major grant from the Davis Educational Foundation supported educational initiatives in the departments of Biology and Biotechnology, Civil Engineering, Computer Science, and Mathematical Sciences. These initiatives will introduce the active, collaborative learning typical of the WPI Plan projects into first- and second-year courses in a cost-effective manner.
- The new Entrepreneurs Collaborative, modeled on the highly successful International Scholars Program, will begin next year. Donald F. Berth '57, outgoing vice president for university relations, and Arthur Gerstenfeld, professor of management, are leading a group of faculty representing most departments in this effort, which will seek to teach students the skills of entrepreneurship.
- The Massachusetts Academy of Mathematics and Science was integrated into WPI's continuing commitment to improving pre-college science and mathematics education. Forty outstanding high school seniors from Central Massachusetts were involved in the pilot-year program. They will all be attending prestigious universities next year; 16 will be enrolling at WPI.
- WPI's highly successful Global Perspective Program continued to expand. The program, which exposes students to other cultures through on-campus programs and through project and course work abroad, has received the support of the Department of Education through its Fund for the Improvement of Post-Secondary Education (FIPSE), the Xerox Foundation, and the U.S. Agency for International Development.

  One of the highlights of the year for the program was the opening of the Ecuador Project Center, the newest of 18 project sites around the world, which saw its first IQP students complete projects. It is anticipated that 221 students will participate in off-campus projects in 1993-94, an increase of 21 percent over 1992-93.
- Major curriculum reviews were accomplished during the year in the Electrical and Computer Engineering, Civil Engineering, Computer Science and Mechanical Engineering departments.

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Above, with professor James Rollings, director of the new Ecuador Project Center, are four of the first five students to conduct projects there: from left, Robert Jessop '94, James Watson '94, Joshua Dobbelaar '94 and John Coyle '94. Right, students work in WPI's Aluminum Casting Research Laboratory.

NEIL NORUM

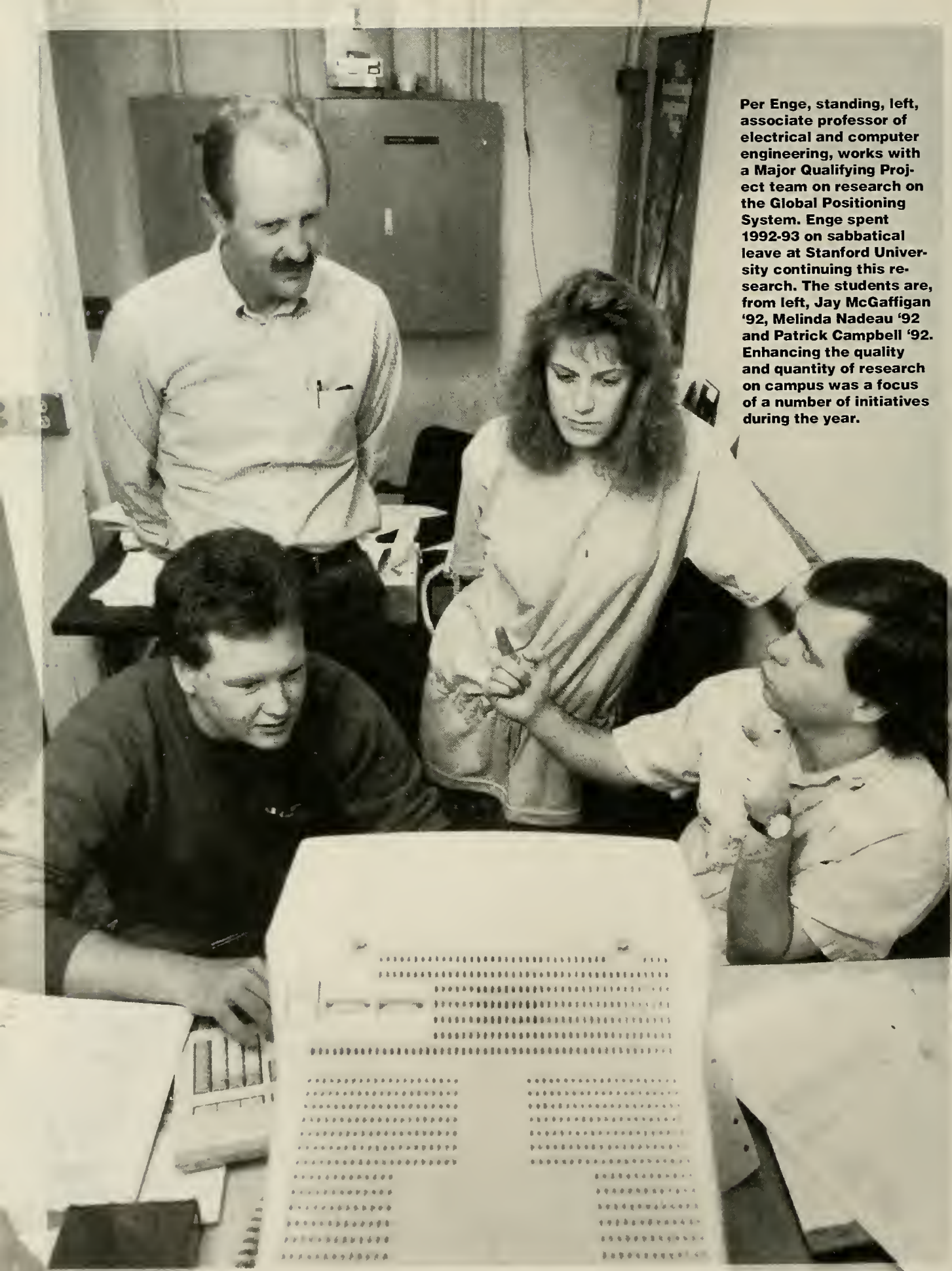
- The Class of 1997 should exceed the budgeted 675 freshmen and will be of excellent quality. Women should constitute 22 percent of the class, up from 18 percent last year. Almost 5 percent of the class will be minorities, up from 2 percent last year. This success is tempered, however, by the fact that to achieve this class WPI admitted 83.5 percent of all applicants, an anticipated yield of 30 percent. The Institute also discounted its tuition an average of 28 percent with institutional financial aid to attract the class. As the Blue Ribbon Task Force pointed out, the recent unfortunate trends in these indicators must be slowed—if not reversed—to assure a viable future for WPI.

Goal 2: Enhance the Level of Excellence in Graduate Education

- At Commencement on May 22, 1993, WPI awarded 28 Ph.D.s. The four-year running average number of doctorates awarded has gone from seven to 21 over the last nine years, a strong testament to the improving quality and quantity of faculty scholarship at WPI.
- Several new graduate programs were developed during the year. They include:
  - a master's degree program in computer and communications, a joint venture of the Electrical and Computer Engineering and Computer Science departments,
  - an interdisciplinary graduate program in the Management of Manufacturing,
  - a joint degree program with the University of Massachusetts Medical Center in biomedical engineering and medical physics,
  - a graduate research internship program developed by the Mechanical Engineering Department in collaboration with the Russian Academy of Sciences, and
  - the new Industrial Internship Program in fire protection engineering.

Goal 3: Increase the Quality and Quantity of Research and its Recognition

- WPI's two new multidisciplinary research centers, the Applied Bioengineering Center and the Center for Intelligent Processing of Materials—made good progress with the help of modest seed funding.
- Research support totaled $5.7 million, an increase of 4.9 percent from the previous



Per Enge, standing, left, associate professor of electrical and computer engineering, works with a Major Qualifying Project team on research on the Global Positioning System. Enge spent 1992-93 on sabbatical leave at Stanford University continuing this research. The students are, from left, Jay McGaffigan '92, Melinda Nadeau '92 and Patrick Campbell '92. Enhancing the quality and quantity of research on campus was a focus of a number of initiatives during the year.

JANET WOODCOCK

period. (This does not include funding for the Center for High Performance Computing and over $1 million in gifts designated to support research.)

- The Realization Manufacturing Coalition, which includes WPI, MIT, Cornell, Tuskegee and North Carolina A&T, was initiated under WPI's leadership with a proposal to the Defense Conversion Technology Reinvestment Program.
- The Aluminum Casting Research Laboratory was designated a Department of Energy Center for Metal Casting under the metal initiative program.
- More than $500,000 in research equipment was obtained through the new Excess Property Program of the federal government.

Goal 4: Enhance the Quality of Life on Campus

Diversity

- Two-thirds of the first class of students in WPI's Strive for College and Careers in Mathematics, Engineering and Science program applied for admission to WPI; 10 will matriculate as members of the Class of 1997. The second Strive class attracted 105 applicants.
- The Office of Human Resources is implementing the recommendations of an affirmative action audit of WPI conducted by the Office of Federal Contracts Compliance Program, a division of the U.S. Department of Labor.
- New initiatives are being explored to attract more minority faculty members. These include partnerships with historically black universities and the recruitment of minority graduate students.
- A special minority student advising program has been developed to facilitate academic success and student retention.

Community Life

- A new $300,000 Fitness Center in the lower level of Alumni Gym opened for business in early September 1992. The facility, funded with anniversary gifts from the classes of 1952, 1953, 1967 and 1968, includes equipment for aerobic exercise and weight training. The center has proven quite popular, averaging more than 300 users per day.
- The new Community Council championed the implementation of the recommendations of the Commission on Residential and Social Life while working to improve the sense of campus community.
- A late-night study facility for individual students and project teams was opened in Fuller Laboratories.
- The Board of Trustees voted to invite representatives from the undergraduate Student Government Association and the Graduate Student Organization to attend its meetings as observers.
- The services of the Career Development Center were expanded to include a job development coordinator, two new telephone information systems, a departmental resume database, a job search support network for alumni and graduating seniors, a bimonthly newsletter, and a variety of training programs.

NEIL NORUM

Goal 5: Meet the Needs of Professionals for Continuing Education

- Ninety professional development seminars were held in such areas as project management, quality improvement, management and communication skills, bar-code technology, and laboratory automation.
- Forty customized in-house training programs were introduced at firms in New England, New York, New Jersey and California.
- Several faculty-led short courses were held on campus.

JANET WOODCOCK

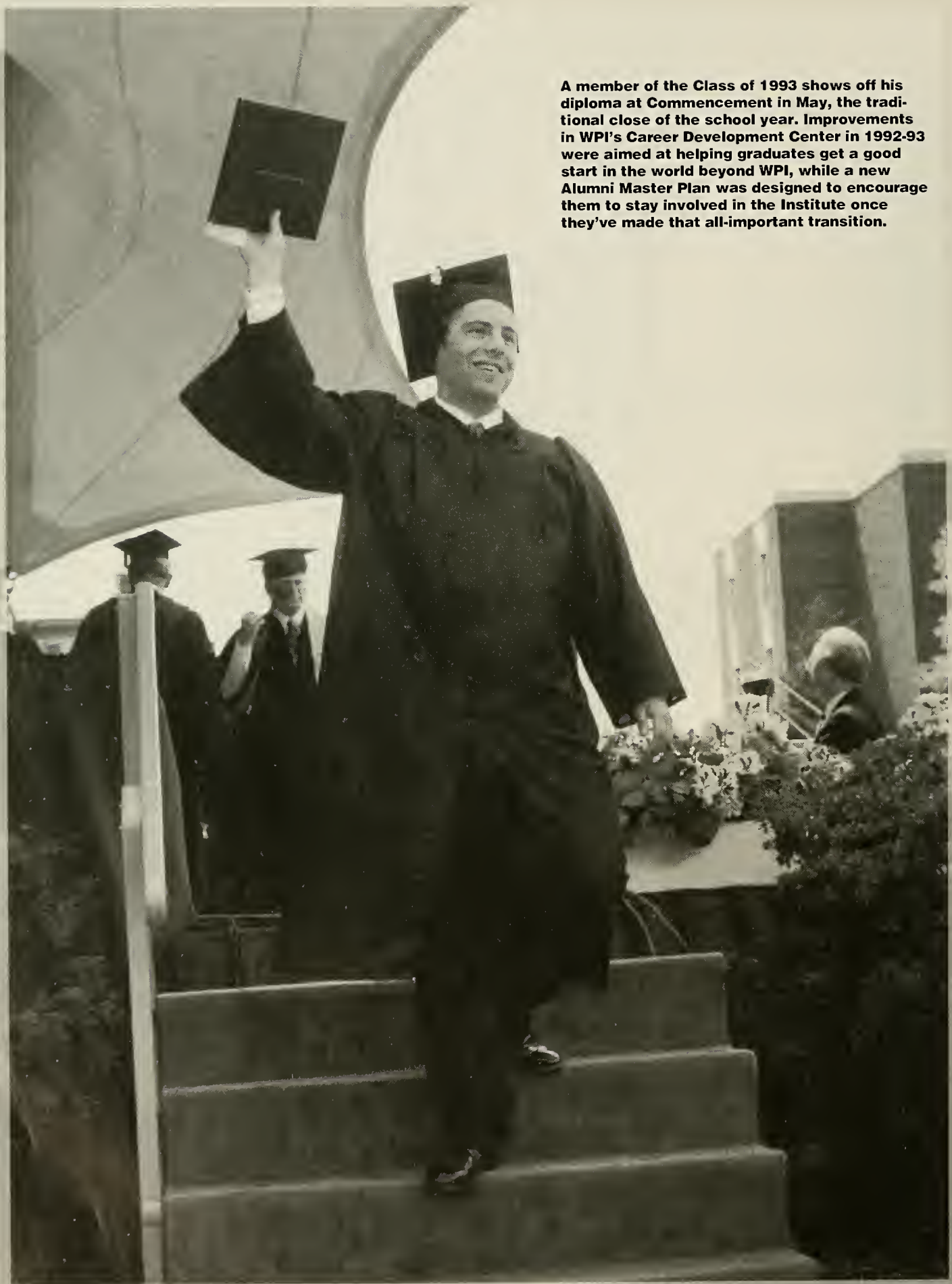
Top, participants in the Nypro Leadership Institute at WPI take part in a team-building workshop. Bottom, the new Fitness Center in Alumni Gym.

Physical Environment

- Lounges, study areas and computer terminals were added to residence halls and academic buildings.
- Graduate student housing was developed in two off-campus houses.
- Responding to student concerns, the WPI Food Service renovated and restructured several of its dining service facilities. Included are a new wok station in Morgan Commons where students can prepare their own meals, a larger grill where items are cooked to order, and expanded healthy choice and vegetarian options. New meal plan options give students greater flexibility in the number of meals they purchase and where on campus they dine.
- WPI's Office of Residential Services inaugurated two special-interest housing alternatives in the fall of 1992. The third floor of Institute Hall became a 24-hour quiet living area and space in Stoddard A was set aside as a substance-free living area. In addition, a grant has been solicited from FIPSE to develop a Healthy Alternatives program and to enhance alcohol education efforts.
- WPI inaugurated the Nypro Leadership Institute, a week-long residency program for mid-level managers from the worldwide facilities of Nypro Corp., a maker of precision plastic industrial components and assemblies headquartered in Clinton, Mass.
- An Advanced Certificate Program was implemented in civil, electrical and mechanical engineering, and in computer science.

Goal 6: Strengthen WPI'S External Relationships

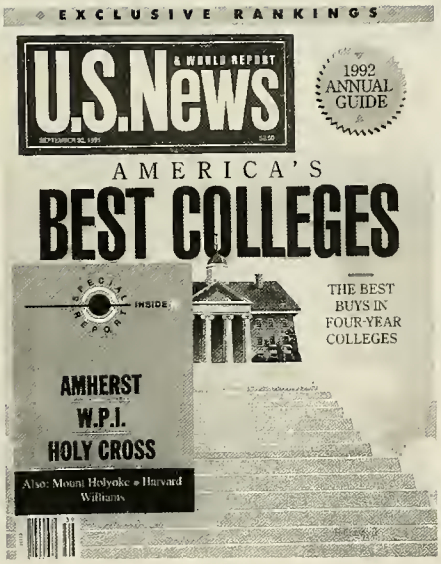
- The WPI Alumni Association developed a new Alumni Master Plan that places greater emphasis on service and involvement.
- WPI was the focus of 300 news stories and several radio and television interviews.

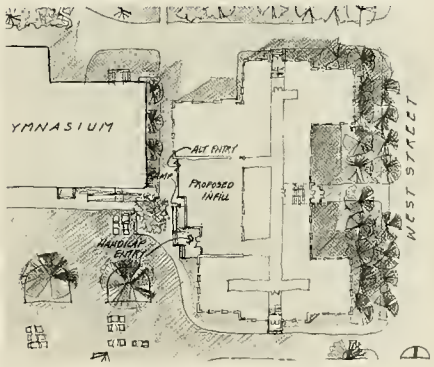


A member of the Class of 1993 shows off his diploma at Commencement in May, the traditional close of the school year. Improvements in WPI's Career Development Center in 1992-93 were aimed at helping graduates get a good start in the world beyond WPI, while a new Alumni Master Plan was designed to encourage them to stay involved in the Institute once they've made that all-important transition.

JANET WOODCOCK

- Once again in 1992, WPI was ranked No. 1 among comprehensive institutions in the North by *U.S. News and World Report.*
- The George I. Alden Society was inaugurated with 154 charter members making planned giving commitments of at least $25,000. The Presidential Founders, which recognizes those with cumulative giving of at least $100,000, added 17 new members.
- The grand total of cash gifts ($9.7 million), gifts-in-kind ($3.4 million) and net new pledges ($4.2 million) for the 1992-93 fiscal year was $17.3 million, exceeding the all-time record of $16.5 million achieved during the *Campaign for Excellence.*
- Two new members were elected to the WPI Board of Trustees during the year: Warner S. Fletcher, attorney and a director of the Worcester law firm Fletcher, Tilton and Whipple, P.C., and Robert A. Foisie '56, president of Matik North America Inc., an import, distribution and services firm specializing in paper-processing machinery. Foisie joined the board in July 1993; Fletcher will take his seat in January 1994.
- The latest book in the "Worcester Polytechnic Institute Studies in Science, Technology and Culture" series, *Representations of Science and Technology in British Literature Since 1880* by Professor Earl Ingersoll of the State University of New York at Brockport, was published in November 1992.





Top, for the third straight year, WPI was ranked at the top of its category in the annual review of America's best colleges published by *U.S. News and World Report.* Bottom, plans moved forward in 1992-93 for a major renovation of Higgins Laboratories. The project may include the construction of a 14,000-square-foot addition to the west side of the building, as shown in these artist's renderings.

Conclusions

The work of the Blue Ribbon Task Force is both a significant accomplishment in its own right and an enormous challenge going forward. The Flansburgh study also presents challenges for the future.

Good progress has been made in planning and funding the renovation of Higgins Laboratories, but needs for more teaching and laboratory space remain to be addressed. The trustees' Physical Facilities Committee is considering how best to create these new facilities in combination with the Higgins Labs renovation. The members of that committee are mindful that these facilities must inevitably compete for philanthropic funds with the campus center and other high-priority capital projects.

In fact, the board's Development Committee has begun work on identifying the funding necessary for completing the Higgins renovations, new laboratory space and the campus center consistent with the BRTF's recommendation that such projects not be funded from the operating budget.

Finally, as we organize long-term efforts to address the BRTF and Flansburgh recommendations, we will have to continue the considerable progress we've made toward achieving the goals of the strategic plan. Of particular concern will be our continuing efforts at maintaining and enhancing our premiere academic programs, recruiting students, developing and maintaining a balanced budget, building recognition, improving diversity, assisting students and alumni with career development, raising funds, and operating our institution. Our work never stops!

Based on the positive reception this past year to open campus meetings conducted by the organizers of a series of budget seminars, by the Community Council, and by the Blue Ribbon Task Force, we will look to involve the campus community in all of these endeavors. And, we will be alert to the BRTF's recommendation to employ the considerable talents of our alumni wherever possible.

Every member of the WPI family should take great pride in the quality of our distinctive institution, the substantial accomplishments of the past year, and the exciting challenges facing us in the future. It is the regular, day-in, day-out hard work of literally every member of this group that provides the environment that makes everything else possible.

While we can't begin to list this work and thank those responsible here, we should all be certain to recognize that some of the best teaching, research, community service, governance, administration, maintenance and support are only noticed in their absence. Against that standard, we do well indeed. We should take pride in these many unsung, but much appreciated, accomplishments.

All this didn't just happen, of course; it was the culmination of the foresight and imagination of our predecessors over the Institute's first 128 years, and of the innovation and diligence of the WPI community of today. With the goodwill and hard work of all of us, WPI's next years promise to be even more exciting and filled with accomplishment.

Saving the Best for Last

By Donald F. Berth '57
Vice President for University Relations

This was the year of George Alden. First, we celebrated the 150th anniversary of his birth on April 22, 1992. On that occasion we formally recognized the charter members of the George I. Alden Society and presented them with specially commissioned charter medallions. Named in Alden's honor, the group was launched at the 1992 Presidential Founders dinner. Its first 154 members had all met the requirement that they provide WPI at least $25,000 through their estates or through another planned giving arrangement.

Crowning the April 22 event was an announcement by Francis Dewey III, chairman of the George I. Alden Trust, that he and his fellow trustees had voted to award WPI a grant of $2.4 million for the renovation of Higgins Laboratories. Combined, the minimum commitments of the Alden Society members and the Alden Trust grant made for a $4.7 million birthday party with WPI as the fortunate recipient.

The $2.4 million grant was the largest in the 81-year history of the Alden Trust and the second largest gift in WPI's long history. It brought the trust's total giving to WPI since 1920 to $10.8 million (half of which we received in the past decade). What a remarkable legacy, one that had its start when a young George Alden, fresh from graduating—summa cum laude—from Harvard, came to WPI in 1868.

Just 25, Alden was the youngest of the original five instructors who greeted the first class of students at the doors of the newly finished Boynton Hall on Nov. 11, 1868. For 25 years, Alden would be synonymous with excellence in instruction and leadership in mechanical engineering at WPI. In 1896, through what would prove to be fortuitous circumstances for WPI, he turned his attention full time to the development of the Norton Emery Wheel Co., eventually becoming its chairman and a wealthy businessman.

It seemed especially fitting to identify WPI's newest donor recognition group with Alden. The planned giving commitments made by the charter members, and those that will be made by future members, are analogous to Alden's own living trust, which continues to benefit WPI significantly today. And the charter membership forms a solid foundation for further development and growth of WPI's total planned giving program. Currently, the value of the various forms of established planned gifts (insurance policies, unitrusts, pooled income funds and known bequests) exceeds $14 million. The Alden Society will help ensure an ever larger and more important flow of resources to WPI in years to come.

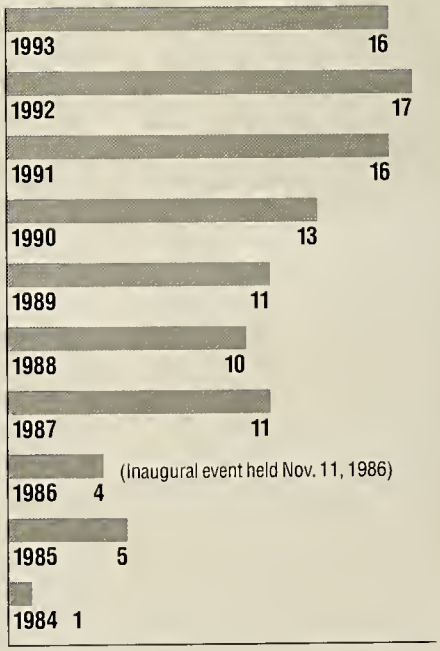
On Nov. 11, 1992 (Founders Day), we celebrated the seventh annual dinner event in honor of our new Presidential Founders—some 17 in all. Our custom has been to choose one founder each year for special attention. In 1992 we recognized Ray Perreault and his late wife, Ina, for their most generous support of many projects and activities before and during the 16 years he has spent on the Board of Trustees. A member of the Class of 1938, Ray continues his active entrepreneurial career as president of Falls Machine Screw Co. in Chicopee, Mass., and his active work for WPI, particularly as a member of the board's Physical Facilities Committee.

Presidential Founders are individuals or family foundations who have given or pledged to the Institute at the level of John Boynton's 1865 "challenge gift" of $100,000. The development and growth of this program has become key to WPI's development momentum at the highest end of the giving pyramid. Since the establishment of the Founders in 1986, a growing number of WPI alumni and friends have been captivated by the magic of "re-endowing" WPI by matching the challenge Boynton made so many years ago. During those seven years, 98 new Founders were added to the roster, bringing the grand total to 202, including Boynton.

Annual giving to WPI's long-running and well-established Alumni Fund is another important component of the Institute's de-

Ray Perreault and his late wife, Ina, in 1978 at the dedication of the renovated Boynton Hall, one of the many projects at WPI the Perreaults supported. Ray and Ina's generosity was celebrated at the seventh annual Presidential Founders dinner in 1992.

New Presidential Founders: Ten Years of Growth



velopment efforts. This year, through the leadership of the Alumni Fund Board and hundreds of volunteers, a new record was established—$1,891,383. With corporate matching gifts, the total reached more than $2.4 million. Nearly 6,000 individuals contributed to this achievement.

This grass-roots giving is extraordinarily important, for it helps provide WPI resources at the margin, where a lack can have greater limiting potential than is often realized. Any successful private institution must continually attract "investors" who represent all levels of support. No alumnus or alumna—young or old—should ever feel that his or her gift is too small to matter. In this regard, I'm pleased that the Fund Board is making a special effort to reach alumni who graduated within the past 10 years to bring them on board as new investors.

> ***"It has been the greatest privilege of my life to have served my alma mater as its vice president for university relations during this run."***

The President's Advisory Council (PAC) set a new membership mark of 224 individuals in FY 1993. This high-end Alumni Fund group includes donors of at least $1,500. Collectively, PAC members established a new giving record of $1,274,908—a little better than two-thirds of the overall Fund total.

It might be worth pointing out that, given the annual nature of this giving program, the funds raised from individual alumni, friends and parents provide a dynamic, continuous income stream. In the absence of the Fund, WPI would need to add an additional $44 million to the value of its endowment (using WPI's current spending rule) to generate the same level of resources.

While the highlights above focus on individual giving, which has accounted for between 60 and 65 percent of our total program over the past decade, our corporate and philanthropic foundation fundraising initiatives also contributed strongly to this year's overall totals. With the Alden Trust grant (payment being spread over four years), foundations provided about $1.6 million in cash. Once again, corporate giving set an all-time record for gifts-in-kind (about $3.4 million) and contributed $2.3 million in cash to the bottom line (including the matching gift dollars from the Alumni Fund).

To calibrate the extraordinary success we realized in Fiscal Year 1993, note that our previous high-water mark for cash and gifts-in-kind was $12,188,900, set in FY 1991. The total for FY 1993 was $13,691,117. The average for the four years of the *Campaign for Excellence* (November 1986 to November 1990) was $9.6 million/year. Our net secured pledges (pledges made during FY 1993 net of partial payments) totaled $4,168,681. Much of this can be credited to the success of the Alden Society launch and the remaining balance on the Alden Trust grant. For FY 1993, then, I am especially pleased to report a grand total of activity of $17,859,798—*an all-time winning year!*

These past 10 years have been a great run for WPI. Overall, some $111 million was generated, enabling the Institute, among many thrusts, to provide for new and improved physical resources, enhance the growth of the endowment, and increase financial aid, all of which has helped us serve as an innovative and caring institution of higher education in these increasingly challenging times.

It has been the greatest privilege of my life to have served my alma mater as its vice president for university relations during this run. I returned to WPI in September 1983, some 30 years—almost to the day—after my parents brought me to this campus as a freshman. Just as was true during my student days and my career elsewhere, a lot of folks have long had to put up with my independence and irascibility; to all of them, through whom and with whom I have been able to accomplish so much, I owe an enduring debt of thanks.

When I set out to take WPI to a much higher (and needed) level of support and recognition, that goal was initially greeted with some skepticism. But as time passed, more and more of you believed—as I did—that we were better and that we could do better, and by doing so make for an even finer institution.

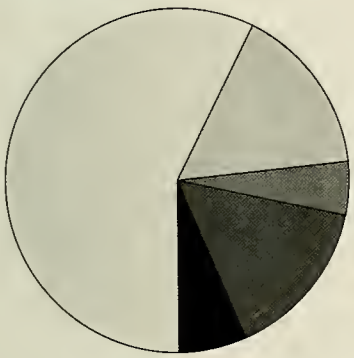
To the investors, to the Board of Trustees, to the presidents I've served, Edmund T. Cranch and Jon C. Strauss, and especially to our staff in University Relations, my thanks for your forbearance and support. My successor, Albert Doig Jr., merits your talent and energy as he takes the baton to run the next leg of this enduring relay. Give him your best!

Fund-Raising Results

(Fiscal Year 1993)

Cash Received

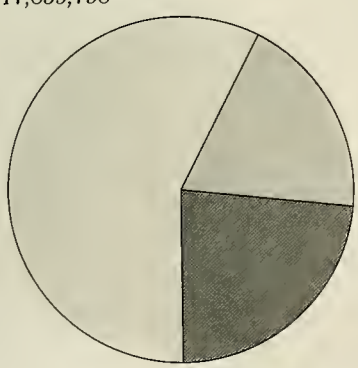
$10,826,287



Individuals	57.5%
Corporations	16.0
Corp. Matching Gifts	5.0
Foundations	15.1
Other	6.4

*Total Activity**

$17,859,798



Cash	57.6%
Gifts-in-Kind	19.1
Net New Pledges	23.3

* Includes all new gifts and pledges received during the fiscal year. In addition to these, there is approximately $24 million in outstanding pledges and other future gift commitments made in previous fiscal years.

Giving to WPI: 1992-93

WPI gratefully acknowledges the support of the thousands of individuals, foundations and corporations whose contributions of $13,691,117 in cash and gifts-in-kind through the Alumni Fund, the Parents Fund, minicampaigns and general development efforts during the 1992-93 fiscal year are already at work making WPI a stronger and more outstanding institution. Space does not permit the listing of all their names. An additional $4,168,681 was pledged during the fiscal year. These commitments will be listed in future reports as they are received as cash or gifts-in-kind.

$100,000 and above

George I. Alden Trust
Altera Corporation
Commonwealth of Massachusetts
Davis Educational Foundation
Digital Equipment Corporation
Estate of Marion S. Fletcher
George F. and Sybil H. Fuller Foundation
General Electric Foundation
Estate of Laura E. Hansen
Howmet Turbine Components Corporation
IBM Corporation
Richard A. Lufkin Trust
Mrs. Luther B. Martin '25
Daniel L. McQuillan '49
Edward H. Peterson '43
Carl E. Rylander '31
Kenneth W. Shiatte '53
Dr. Stedman W. Smith '36
Stoddard Charitable Trust
Estate of Dorothea M. Styffe
Edward J. and Mildred P. Sydor '50
United Technologies Corporation
Viewlogic Inc.
Estate of Katharine Wellington
Joy P. and Leonard A. Young '37 Trust

$25,000 to $99,999

AT&T Corporation
Philip G. Atwood '37
Mrs. David C. Bailey '25
Eleanor W. Bateman
Robert H. Beckett '57
Mrs. Harold S. Black '21
Cerberus Ltd.
Estate of Mary M. Clarkson
Clearpoint Research Corporation
Raymond B. Crawford '33
Charles H. Decater '28
Robert E. Duffy '45
Exxon Education Foundation
Ford Motor Company Fund
Estate of Moxie F. Goll
Winfield D. Gove '24
GTE Corporation
John P. Harding Jr. '47
Hewlett Packard Company
Milton P. Higgins
Hoche-Scofield Foundation
Rolf Jensen & Associates
Edwin L. Johnson '33
Kemper National Insurance Companies
Estate of Mary C. Knight
Liquid Carbonic R&D Group
The Macamor Foundation
Herman Medwin '41
S. Bailey Norton Jr. '43
Norton Company
Francis J. Oneglia '42
Windle B. Priem '59
Procter & Gamble Company
William L. Raymond Jr. '44
Raytheon Company
Mrs. Franklin Roberts '33
John T. Rushton '39
Schlumberger-Doll Research
Mrs. Arthur E. Smith '33
The Starr Foundation
State Farm Company Foundation
WPI Alumni Association
Xerox Corporation

$10,000 to $24,999

Aetna Life and Casualty Company
American Nuclear Insurers
BASF Corporation
Anna Harrington Boardman
John R. Brand '36
Martin G. Bromberg '51
Cambridge NeuroScience Inc.
Brian D. Chace '69
Carl C. Clark '45
Richard A. Davis '53
Dining and Kitchen Administration Inc.
Mrs. Robert H. Field '38
Raymond J. Forkey '40
Milton W. Garland '20
Alfred E. Green '45
Steven C. Halstedt '68
Hartford Steam Boiler Inspection and Insurance Company
Marie B. Knowlton Trust
Paul N. Kokulis '45
David A. Kuniholm '40
M. Leonard Kuniholm '38
Gordon B. Lankton
Massachusetts Electric Company
Myles McDonough
Mobil Foundation Inc.
Motorola Inc.
Douglas G. Noiles '44
Northeast Utilities Service Company
Roger N. Perry Jr. '45
Mrs. George W. Petrie
Clark L. Poland '48
Albert W. Rice Charitable Foundation
Sean D.S. Sebastian '83
John J. Shields '69
Raymond B. Shlora '40
Robert C. Stempel '55
William R. Steur '35
Frans E. Strandberg '39
Wyman-Gordon Company

$5,000 to $9,999

James S. Adams '49
David E. Beach '53
C. Edward Bean '44
Richard A. Beth '27
J. Richard Bullock
Harold D. Burt '33
CIGNA Corporation
Dr. and Mrs. Noel L. Cohen *p*
Daniel I. Coifman '67
Herbert W. Coulter III '70
Donald G. Craig '57
Paul M. Craig Jr. '45
Michael A. DiPierro '68
Mrs. Dwight Dwinell '34
John E. Edfors '55
Robert E. Fay Jr. '44
Kidde-Fenwal Inc.
Robert Fowler Jr. '36
Dale G. Freygang '74
Francis J. Gamari '54
Richard T. Gates '52
A.J. Gifford Charitable Trust
Greater Worcester Community Foundation
Grinnell Corporation
Philip A. Henning '45
John E. Hossack '46
Johnson Controls
Owen W. Kennedy Jr. '45
Richard B. Kennedy '65
Arthur R. Koerber '40
Carl J. Lindegren III '82
Manostat Corporation
Samuel W. Mencow '37
Mrs. Joseph C. Molder
Monsanto Company
Neles-Jamesbury Corporation
The Nellie Mae Fund
New England Power Company
New England Power Service Company
David P. Norton '62
OmniGene Inc.
Robert S. Parks '93 Trust
Perkin-Elmer Corporation
Polaroid Corporation
The Presmet Corporation
Richard Prouty
L. Howard Reagan '44
Estate of Louis Sherman
Silvaco International
J. Morrison Smith '37
Donald Taylor '49
John G. Underhill '44
WPI Worcester County Club

$2,500 to $4,999

Paul A. Allaire '60
Allendale Mutual Insurance
Anonymous
Anonymous
Kenneth E. Baker Sr. '52
Paul W. Bayliss '60
Craig Beyler and Judy Hartman
Allen L. Brownlee '33
Arthur H. Burr '29
James L. Carr Jr. '74
Class of 1942
Charles H. Cole '30
Data Translation Inc.
Day Family Foundation
Fredrick DeBoer '53
Dow Chemical Company
Dr. Howard J. Dworkin '55
Leland P. Ekstrom '42
Richard S. Fitts '45
Neil A. Fitzgerald '38
John F. Gabranski '75
Michael M. Galbraith '58
Herbert F. Gale '34
Mrs. Allan Glazer '47
Albert S. Goldberg '48
Robert W. Goodfader '60
Bennett E. Gordon Jr. '65
W.R. Grace & Co.
Edward L. Griffith Jr. '69
Michael S. Gutman '58
Raymond R. Hagglund '56
Daniel J. Harrington Jr. '50
Robert W. Hewey '40
Hughes Aircraft Company

Note: a "p" after a name indicates parent(s) of WPI students/alumni.

Industrial Risk Insurers
Ingersoll-Rand Company
Rolf H. Jensen
Charles C. Johnston '57
Franklin S. June '45
Margaret N. Kalenian
Paul J. Keating II '64
John F. Kelley III '65
Victor E. Kohman '43
William M. Lester '28
Marsh & McLennan Companies Inc.
Frank D. Meoli '70
Alfred A. Molinari Jr. '63
Morgan Construction Company
National Fire Protection Association
John M. Nelson
Henry W. Nowick '56
R. Craig Pastore '69
Pfizer Inc.
Henry B. Pratt '32
Public Service Electric and Gas Company
Irving M. Roberts '43
Kenneth W. Roberts '68
Mrs. Franklin Robinson '43
Rodney Hunt Company
Sara Lee Corporation
Lawrence F. Scinto '51
The Stanley Works
Stone & Webster Inc.
Jon C. and Jean A. Strauss
Mr. and Mrs. Roger Sullivan *p*
Howard E. Swenson '44
Texaco Inc.
Leonard H. White '41
Kimball R. Woodbury '44

$1,500 to $2,499

Walter L. Abel '39
Michael L. Abrams '77
Acton Research Corporation
Robert H. Adams '48
American Cyanamid Company
Arnold J. Antak '68
Arthur Andersen & Company
Herbert Asher '44
Roy E. Baharian '44
Bruce M. Bailey '51
Richard A. Barlow '57
Lawrence B. Barnard '29
Jonathan R. Barnett '74
James L. Bartlett Jr. '39
Bechtel Group Inc.
Peter M. Bell
L. Thomas Benoit Jr. '66
Harvey A. Berger '58
Donald F. Berth '57
Paul R. Beswick '57
Black & Decker Corporation
Roland C. Bouchard '66
J. William Bowen '66
John Lott Brown '46
Paul W. Brown Jr. '55
Daniel A. Bundza '57
John K. Busada '39
Wilder R. Carson '39
Hsien D. Chang '70
Edwin B. Coghlin Jr. '56
David S. Crimmins '58
Gordon F. Crowther '37
George H. Crozier Jr. '53
Henry S.C. Cummings Jr. '50
Earl M. Curtis '36
Walter G. Dahlstrom '36
C. Marshall Dann '35
Mrs. Phillip R. Delphos '26
William A. Delphos '74
Albert M. Demont '31
William P. Densmore '45
Robert L. Diamond '56
Walter G. Dick '49
Paul C. Disario Jr. '42
Cornelius J. Enright Jr. '60
Robert H. Farrar '56
Robert L. Favreau '52
Gerald Finkle '57
Patricia A. Graham Flaherty '75
The Foxboro Company
Daniel A. Funk '77
Anson C. Fyler '45
Michael Gaffin '55
Mark S. Gerber '69
The Gillette Company
Joseph Glasser '35
Joel P. Greene '69
Peter T. Grosch '69
Ralph P. Guertin '62
David H. Hall '68
Leslie B. Harding '41
Warren G. Harding '42
Stephen J. Hebert '66
Thomas S. Heefner '61
Jacob Hiatt
Jay P. Hochstaine '62
D. Brainerd Holmes
Peter H. Horstmann '55
Holbrook L. Horton '29
Mr. and Mrs. William Henry Hough *p*
L. Brewster Howard '36
Clayton E. Hunt Jr. '34
Larry Israel '61
Leonard Israel '44
M Howard Jacobson
Harry T. Jensen '33
Edwin S. Johanson '45
Fritz E. Johanson '40
Chandler W. Jones '26
Steven M. Kay '72
Averill S. Keith '43
William A. Kerr '60
Ajay Khanna '92
Marshall J. Kidder '53
Douglas W. Klauber '67
Hans H. Koehl '56
Wilmer Kranich
Ernest R. Kretzmer '45
Walter E. Lankau Jr. '64
Carl E. Larson Jr. '37
John H. Lauterbach '66
John B. Lawson '63
Eino O. Leppanen '32
Allen H. Levesque '59
Frederick W. Lindblad '42
Arthur J. LoVetere '60
Russell R. Lussier '54
Joseph J. Maggi '67
F. William Marshall Jr. *p*
Zareh Martin '40
Thomas G. McGee '64
John M. McHugh '56
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Joan M. Bolduc Szkutak '79
Robert M. Taft '38
Alvin E. Tanner '57
Norman J. Taupeka 'S8
Marshall B. Taylor '68
William R. Taylor 'S5
Tech Old Timers
Teledyne Charitable Trust Foundation
Tenneco Inc.
Edwin D. Tenney 'S9
Harry W. Tenney Jr. 'S6
Nishan Teshoian '63
Texas Instruments Foundation
Peter A. Thacher '74
Thiokol Corporation
Leo J. Thomas
J. Headen Thompson '36
John S. Thompson Jr. '69
Norman J.A. Thompson
Ronald E. Thompson Jr. '82
Emery F. Thoren Jr. '71
George T. Thrasher '67
James M. Tolos '61
David A. Tone '63
Paul G. Trudel '67
Alden F. Tucker 'S2
Robert M. Tucker '28
Stephen J. Turek Jr. '44
Turner Corporation
Paul W. Ulcickas '63
Oliver R. Underhill Jr. '31
Mrs. L. Ivan Underwood '2S
United Engineers & Constructors International Inc.
The United Illuminating Company
U S West Foundation
Mr. and Mrs. Lloyd S. Van Ess *p*
Milford R. VanDusen '47
Shirley Hossack Van Winkle
Henry A. Vasil '53
Spiro L. Vrusho 'S7
Kenneth R. Wadland '72
William M. Walker '43
Richard W. Wallahora '68
William M. Walsh 'S3
Warner-Lambert Company
Burl S. Watson Jr. '49
Steven C. Watson '71
Mr. and Mrs. John P. Wattu *p*
John B. Weigele '73
Clifford M. Weiner '81
J. Richard Weiss Jr. '42
Mr. and Mrs. George E. Wellman
Axel H. Wendin '26
John J. West Jr. '88
Westinghouse Electric Company
Westvaco Corporation
Edward C. Wheaton
Robert J. Whipple
Whirlpool Corporation
Harold E. White '39
Jeffrey D. White '84
Mark D. Whitley '73
George E. Whitwell '77
Plummer Wiley '3S
George D. Williams '44
John H. Williams Jr. '47
Rohert S. Williamson '31
Gary E. Wnek '77
Bruce W. Woodford '61
Charles E. Woodward '31
Robert D. Woog '68
John D. Writer 'S1
Yang Xu '91
Anthony J. Yakutis '43
Joseph A. Yanikoski '87
Anthony E. Yankauskas '71
Yankee Atomic Electric Company
Mr. and Mrs. Alan F. Yates
Robert A. Yates 'S7
Thomas P. Zarrilli '76
William E. Zetterlund '6S
Mary M. Zoeller '73